JPRS 81599

20 August 1982

USSR Report

SPACE BIOLOGY AND AEROSPACE MEDICINE

Vol. 16, No. 4, July-August 1982

FBIS FOREIGN BROADCAST INFORMATION SERVICE

164

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Translation of the Russian-language bimonthly journal KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA published in Moscow by Izdatel'stvo "Meditsina".

CONTENTS

PUBLICATION DATA

English title	:	SPACE BIOLOGY AND AEROSPACE MEDICINE, Vol 16, No 4, July-August 1982
Russian title	:	KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA
Editor	:	O. G. Gazenko
Publishing house	:	Meditsina
Place of publication	:	Moscow
Date of publication	:	July-August 1982
Signed to press	:	4 June 1982
Copies	:	1438
COPYRIGHT	:	"Kosmicheskaya biologiya i aviakosmicheskaya meditsina", 1982

SURVEYS

UDC: 629.78:612.821.1/.3]:658.311.44

MAIN DIRECTIONS AND PRINCIPLES OF PSYCHOLOGICAL EXPERTISE OF COSMONAUTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 8 Sep 81) pp 4-8

[Article by K. K. Ioseliani, A. L. Narinskaya and Sh. R. Khisambeyev]

[English abstract from source] This paper attempts to systematize the major objectives and principles of psychological expertise of cosmonauts during their selection and training which may contribute to well-substantiated conclusions.

[Text] Because of the increased duration of spaceflights, greater complexity and fullness of flight programs, greater demands are being made of the cosmonaut, which sometimes border on the limits of his psychophysiological capabilities. The professional activity of a cosmonaut, who is exposed to such specific flight factors as weightlessness, noise, vibration, sensory deprivation, relative social isolation, shortage of time, etc., require emotional stability, intellectual vigilance and effectiveness, quickness of wit, creative thinking and other psychological traits that assure the speed and adequacy of reactions to complicated flight conditions. Consequently, it is necessary to impose high demands of individual psychological, personality and professional qualities of cosmonauts to assure the reliability of the cosmonaut-spacecraft system.

We use the term, psychological expertise of cosmonauts, to refer to the set of psychological examinations at the stages of screening, routine and special certification and special training, which are aimed at finding individuals whose psychological and personality traits make them fit for professional work with specific space equipment.

All of man's distinctions, his psychological productivity, compensatory and reserve capacities are not essentially static; they change, sometimes quite significantly, depending on exogenous and endogenous factors, which leave a marked impression on the entire personality in a number of cases.

For this reason, the system of psychological expertise, which is an organic element of general clinical expertise, is not limited to regulated certification of cosmonauts, but includes dynamic psychological monitoring at the training, spaceflight and postflight stages [1, 2].

The teaching on correlation between congenital and acquired qualities, personality traits that form abilities, is the basis of theory of psychological expertise.

Professional capacities are the aggregate of rather stable individual psychological traits of man, although they do change under the influence of rearing, which determines the success of learning a specific work activity on the basis of compensation of some personality traits with others [3].

Since the personality is always characterized by the individual structure of personality traits, the extent of its conformity to the requirements of a given activity determines the professional fitness of an individual.

Soviet psychologists believe that abilities (including flying) are not inborn; they are formed under the influence of concrete living conditions, upbringing and education of an individual [4, 5]. Only the anatomical and physiological distinctions of organization of the brain and its functions, in particular, the typological properties of the nervous system, are congenital [6, 7]. For this reason, theoretically any physically and mentally healthy person could learn the profession of cosmonaut. However, practice demands consideration of factors of quality, time and economic expediency.

Each new program of spaceflights followed by cosmonauts of the USSR and United States was instrumental in upgrading the system of psychological expertise of cosmonauts.

In the USSR, this system developed from the knowhow in aviation psychology, and the "reproduction" principle was used as its foundation [8]. This was manifested by an original methodological approach, which combined observation with continuous multieffector recording of a number of physiological parameters and experimental creation of a model situation that reproduces the different aspects of the difficult conditions involved in professional work of cosmonauts. Subsequently, the system of psychological expertise was perfected in the course of the Vostok, Voskhod and Soyuz missions [1, 9-12].

At the present time, expert psychological evaluation of cosmonauts is made by means of a set of psychological and physiological techniques with simulation of stressogenic spaceflight factors, which permits assessment and forecasting of the cosmonaut's functional and psychological capabilities, as well as his work capacity as it relates to spaceflight conditions [13-15].

In recent years, personality techniques borrowed from foreign practice have been used as additional methods (thematic apperception test, Minnesota Multiphasic Inventory, Rosenzweig Picture Frustration Study, Eysenck's, Taylor's questionnaires and others), as well as intelligence tests (Wechsler's Raven's and others). While they have a number of advantages, they are not without substantial flaws, the most important of which is that the present level of technique in interpreting these tests does not provide sufficient reliability of conclusions and complete independence thereof of the experimenter [16-20].

It is apparent from American sources [21-23, 24] that there are no basic differences between the systems of psychological expertise in the United States and the USSR. American specialists devote much attention to motivation and social adjustment to the detriment of more objective psychological and physiological methods.

Proceeding from the fact that the professional activity of a cosmonaut is, in its general psychological essence, a process of reception and processing of incoming information, decision making and handling the system he controls, it is based on the following professionally important psychological properties: capacity for complex differentiating activity of a sensory nature; good operative memory; development of attention properties (volume, concentration, switching, distribution); capacity to retain work capacity in more difficult situations and when time is short; rapid learning and alteration of mental work skill; ability to assess available time and plan one's action accordingly; ability to make a decision when there is a shortage of information; rapid mental processes; good spatial orientation; capacity for rapid and precise motor reactions; ability to forecast a situation, predict possible changes, ability to distinguish what is important in a flow of information; ability to control one's actions; intellectual initiative and flexibility; operative [effective] thinking--detection of a problem situation, definition of the problem and finding the means of solving it. Emotional stability is an important trait, as well as temperament features, in which are manifested elements of strength, lability and equilibrium of nervous processes.

More than 20 years of experience with spaceflights makes it possible to single out four main directions of psychological expertise of cosmonauts.

1. Demonstration of adverse individual psychological personality traits that prevent successful learning and performance of professional activity.

2. Obtaining psychophysiological data to define diagnoses when there are some deviations of health status and providing a validated expert decision.

3. Determination of functional psychological capabilities of the individual when exposed to specific factors.

4. Investigation of the effects of real spaceflights on the psychological side of the cosmonaut.

We shall describe below these directions in detail.

1. Adverse individual psychological personality traits for the profession of cosmonaut are: weakness, inertness, imbalance of nervous processes; scattered and unstable interests and inclinations (particularly those related to cosmonaut activity); indecisiveness, lack of courage; likelihood of disruption when it is necessary to work when time is short and there are interferences; slown and uncritical thinking; instability, exhaustibility of attention; slow attention switching and distribution; slow and inaccurate sensorimotor coordination; diminished memory; difficulty in operating with spatial conceptions; emotional instability; low intelligence.

It must be borne in mind that the above traits may not only be the individual psychological distinctions of a healthy person, but symptoms of incipient overfatigue or neuropsychological disease. For this reason, the individual psychological distinctions should be assessed with consideration of all data on development of the personality and dynamic medical supervision.

2. Use of psychological examination to pinpoint the diagnosis of certain diseases constitutes an important task of psychological expertise. The demonstrated decline of memory, attention, inhibition of mental processes combined with marked fatigability when performing mental work and low productivity in given tasks, with slow work pace, may sometimes be the only manifestations of the early stage of cerebrovascular sclerosis [24].

A psychological work-up expands the possibilities of diagnosing long-term sequelae of cerebrocranial trauma and yields data for furnishing a validated expert decision. It is used as a criterion of restoration of impaired functions following relatively recent cerebrocranial trauma. Instances are not uncommon when individuals who have sustained cerebrocranial trauma have residual posttraumatic manifestations that are demonstrable only by the psychological examination (diminished memory, deviations in higher associative processes), together with the results of some functional [load] tests (EKG and neurological examination while breathing with a gas mixture). The obtained data can be used as a criterion of reversibility or, on the contrary, persistence of posttraumatic changes.

A psychological examination may be helpful in differentiating between persistent pathological mental states and temporary neurotic reactions [25]. In a number of cases, repeated psychological examinations (occasionally at intervals of 1.5-2 months) permit demonstration of the reactive and, consequently, reversible nature of such states.

3. The distinctive feature of the third direction of psychological expertise is that it is performed under natural conditions: various training meets, "survival" experiments with relative social isolation of cosmonauts under difficult climate and geographic conditions (mountain climbing, downhill skiing on steep slopes, prolonged cross-country skiing over rugged terrain in regions of moderate altitudes, spending many hours in special gear, parachute jumping, etc.) [1]. Being exposed to such situations and active in them, which is associated with diverse stressogenic and sometimes extreme factors, elicit emotional instability, absent mindedness, loss of mental balance, lack of confidence, disorganization of activity and refusal to continue with it in some people, whereas in others it elicits only insignificant excitement and general working tension, which is instrumental in overcoming the stressogenic situations [26].

The expert psychologist thus has vast opportunities to assess the personality, information about its emotional and conative aspect, reactions, individual psychological traits, psychophysiological reserves of the body, adaptive capabilities, etc. The obtained data make it possible to define the initial expert decision and formulate a forecast for subsequent stages of training.

Conversation and observation are the principal methods of obtaining information at this stage. In some cases, depending on the problem and distinctions of the stressogenic situation, a special set of instrument and form [test] methods is used.

4. Study of the influence of flight conditions and factors, as well as volume and nature of work done, on the main mental functions, personality traits and work capacity of cosmonauts during flights and in the recovery period in order to determine the current work capacity, elaborate recommendations on psychopreventive measures at different stages of the adaptation period and improve the system of psychological expertise.

Determination of level of group interaction in a specific crew at the stage of manning crews and crew training constitutes an independent task for psychological expertise; it has been discussed in detail by F. D. Gorbov and M. A. Novikov [27, 28].

The measures used for psychological expertise of cosmonauts must be planned with due consideration of the main principles determining the content and form of such measures.

1. Personality approach, i.e., viewing the cosmonaut's personality and his different mental traits together with activity. According to this principle not a single mental phenomenon manifested by activity can be correctly understood without consideration of its personality-related determination. In the course of psychological expertise, determination and evaluation must be made of socially determined personality traits: orientation of interests, goal orientation, activity with regard to the candidate's choice of the cosmonaut profession. The content of this principle refers to the study of motivation and degree of professional orientation of the personality.

Altogether, these data are used to implement an important principle of Soviet medical expertise, the principle of individual appraisal, which makes it possible, as an exception, to make a decision as to fitness according to the items in the schedule of diseases that determine unfitness.

2. The complex approach signifies that, in professional expertise of cosmonauts, there must be evaluation of fitness of a cosmonaut candidate according to an aggregate of parameters (physical, mental, social and others). In other words, professional expertise must be systemic in nature. The main task for psychological expertise in the aspect of complexity is to study the main mental functions (attention, memory, thinking, emotional stability and work capacity as a whole) under different working conditions and with simulation of psychological factors of flights.

3. Dynamic (stage by stage) expertise refers to a wise order of measures that provide for accumulation of information in the different stages of expertise. In view of the fact that some psychological parameters show some variability under the influence of learning, training, accelerations [or loads], etc., psychological expertise of cosmonauts must be effected at

the following times: psychological screening; scheduled [routine] and unscheduled certification; before assignment to a group for training on a concrete space program; just prior to a flight.

The scope and form of psychological work-up should change at each stage, depending on the objectives and allocated time.

4. Activity of psychological expertise: One cannot attain a high degree of efficiency of the cosmonaut-spacecraft system solely by means of professional screening and expertise. A set of medicotechnical and ergonomic measures to optimize this system is required, and this implies the need to make use of the findings of psychological examinations not only to settle the question of cosmonaut fitness for a special activity, but to adapt equipment to the psychological capabilities of a man working in space, for wise automation of a number of regular operations, to refine the training system, to alter the information model of interaction between cosmonauts and space equipment, etc.

5. Differentiated nature of psychological expertise refers to the fact that one should develop and use, as much as possible, the appropriate sets of methods of psychological examination when different groups of cosmonauts are involved (cosmonaut candidates, candidates for scientist-cosmonauts, cosmonauts, cosmonaut-researchers [scientists]), since the professional activity of different categories of cosmonauts has its own specifics and typical distinctions, which make it necessary to use a differentiated approach to expert decisions. In addition, one has to use a number of methodological procedures that determine general psychological traits required in cosmonauts of all categories.

Development of the above-mentioned directions and principles in the system of psychological expertise of cosmonauts will improve the psychological reliability of the human element in the cosmonaut-spacecraft system and thereby be instrumental in successful performance of tasks pertaining to exploration of space.

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UDC: 629.78:[617-089+616-036.882-08-039.72

ANESTHESIA, SURGERY AND RESUSCITATION DURING MANNED SPACEFLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 15 Apr 81) pp 9-12

[Article by L. L. Stazhadze, I. B. Goncharov, I. P. Neumyvakin, V. V. Bogomolov and I. V. Vladimirov]

[English abstract from source] When exploring the problems of medical aid to be rendered in manned space flights, it is necessary to take into consideration the specific features of the environment as well as the changes in the human body induced by space flight effects. In space flight anesthesia can be applied using such advanced methods as multicomponent balanced anesthesia and peridural anesthesia. Surgery and resuscitation can be performed, employing the procedures and methods that allow operations in an abacterial environment, correction of vital dysfunctions with the aid of aritficial pulmonary ventilation, cardiac electrotherapy, and sorptive purification of body fluids. Various aspects of infusion treatment and first medical aid are discussed.

[Text] Several tasks are advanced pertaining to assuring the safety of manned spaceflights and refinement of the medical aid system in view of expansion and complication of programs of space research [1-3]. Questions of rendering specialized medical care to crew members with onset of life-endangering states during a spaceflight are the most difficult to resolve [4-8].

The probability of such states is based on the theoretical possibility of sudden emergency situations, progression or complication of various somatic diseases or functional disorders during the flight period [4, 8, 9-11]. It may be impossible to return to earth either for technical reasons, or due to the fact that the patient cannot be transported or tolerate the additional accelerations and inertial impact factors concomitant with the descent phase [5, 10]. Under such conditions, a situation may arise that requires rendering specialized medical care while in spaceflight.

The specific conditions of spaceflight determine the requirements of both methods and means of medical care. Most of the traditional methods of emergency medicine are not applicable in spaceflight or require appreciable transformation.

When working on problems of medical aid, it is imperative to take into consideration the functional deviations in cosmonauts under the influence of spaceflight factors, in addition to their specific habitat [2, 12, 13], which could have a substantial influence on the clinical course of possible diseases or other pathological states that are the consequence of extreme factors.

Problems of anesthesiological, surgical and resuscitation aid move to the fore in the presence of emergency and life-threatening states.

Anesthetization may be required during a spaceflight, not only to accompany surgical intervention, but as an element of therapeutic measures when there are pain syndromes of diverse genesis. The series of studies we conducted on volunteers, on the model of antiorthostatic [head tilted down] hypokinesia lasting 7 to 182 days, enabled us to demonstrate the pharmacodynamic distinctions of different anesthetics and clinical course of anesthesia as related to reactivity of the body and stage of adaptation to the simulated flight factors [4, 5, 14]. Cardiorespiratory deviations and maximum metabolic changes were noted with the use of anesthetics and other pharmacological agents, the pharmacodynamics of which coincide with the direction of functional deviations that develop in the body with antiorthostatic hypokinesia. The programs and dosage of anesthetics for general anesthesia were optimized on the basis of these studies. An original technique involving multicomponent balanced anesthesia, in which the pharmacological agents are used in subanesthetic dosage, was found to be the most adequate general anesthesia method [4]. It was proven that the general clinical course of anesthesia was controllable, harmless and corrective.

It is important to note that the use of inhalation anesthetics is inadmissible in the confined and limited space of a spacecraft. Intravenous forms of anesthesia also present technical difficulty, primarily due to the difficulty in reliably separating fluid and gas in the perfusion system. Most of the studied types of general anesthetics, including multicomponent balanced anesthesia, imply administration of artificial ventilation of the lungs, which is undesirable, considering the limited number of spacecraft crew members.

Local [regional] anesthesia methods are advanced to one of the main places in the system of anesthesiological aid by the specific conditions of the cosmonauts habitat and activity. In particular, as shown by special experiments and clinical studies, use of auricular acupuncture combined with electroanalgesia according to a method that has been developed produces local anesthesia in some cases that is sufficient not only to curb the pain syndrome, but for extracavital surgical intervention [5]. Prolonged peridural anesthesia, which yields satisfactory anesthetization and relaxation, with retention of consciousness, adequate spontaneous respiration and possibility of operator work, which is particularly important under self-contained conditions, is a promising form of regional anesthesia under spaceflight conditions. A technique has been experimentally refined and submitted to clinical trial for long-term peridural anesthesia in individuals with altered reactivity.

Surgery in the event of traumatic injury or acute disease during spaceflights should be undertaken in exceptional cases, when all of the possibilities of

conservative therapy have been exhausted. Local hypothermia of the stomach or general external abdominal hypothermia is a rather promising method of conservative therapy for inflammatory diseases of abdominal organs (pancreatitis, appendicitis) or gastrointestinal hemorrhages.

Theoretically, there may be situations during a manned spaceflight when it is necessary to have surgical intervention, and this requires development of a special set of equipment and instruments. It was proven experimentally that it is theoretically possible to perform surgery in weightlessness during flights aboard aircraft in Kepler's parabola. At the same time, the increased bacterial contamination of the limited room in a spacecraft, as well as diminished immunoreactivity when man spends a long time in spaceflight [12, 13] make it necessary to search for basically new approaches to solving this problem. Soft surgical abacterial chambers [tents?], made of transparent fluoroplastic [teflon] film with 2-3 pairs of sleeves with surgical gloves built into them are the most promising devices for both minor surgery (wound treatment) and cavitary operations. Use of such chambers rules out contact of medical personnel with medical supplies, lowers the possibility of infection of the surgical wound. Experimental and clinical studies have confirmed the high effectiveness of this variant of a gnotobiological chamber for surgical interventions.

The rigid requirements of reliability and size-weight characteristics of medical support equipment in manned spaceflights make it imperative to develop a compact set of surgical instruments, which is achieved by using lightweight alloys and standardized removable parts. The methods and means of sterilizing surgical instruments to assure prolonged storage in sterile condition constitute an independent problem. The properties of dressing and suture materials can be expanded substantially by imparting to them bactericidal and hemostatic features, as well as capacity for resorption in body tissues.

As shown by our studies, in developing the ways and means of resuscitation, one msut take into consideration, first of all, changes in functional state of the cardiovascular system, changes in hydration status, deviations in sympathoadrenal and kallikrein-kinin systems and fluid-electrolyte balance, which arise under the influence of spaceflight factors [9-11]. In view of the redistribution of fluids in the body under the influence of weightlessness, in treating life-endangering states of any genesis special attention should be given to prevention, detection and treatment of cerebral edema. An extremely important fact is that, in weightlessness, conditions are created for increased hydration of cerebral structures, which is potentially dangerous for development of swelling and edema of the brain in the event of a life-threatening state. Along with development of various methods of dehydration therapy, including use of osmotic diuretics, one should develop methods of cerebrocranial hypothermia.

Specialized resuscitation provides for correction of critical disturbances referable to external respiration and cardiac function. Along with development of methods to correct these disturbances with drugs, one should not

overlook machines for artificial ventilation of the lungs, as well as electro-pulse therapy of cardiac disturbances which are designed for use during spaceflights. The distinction of this equipment from that used in clinical practice is compact execution, self-contained nature, simple operation and low electric capacity.

It is known that many states (renal, hepatic insufficiency, traumatic injuries, exogenous poisoning) are associated with accumulation of toxic metabolic products in blood. Our studies revealed that a rahter effective method for combined therapy of endo- and exo-intoxication is purification of biological fluids (blood, plasma, lymph) through various sorbents. Extensive clinical trials have shown the potential of the method of sorption purification of blood in the presence of various diseases [16, 17].

To introduce this method into space medicine practice, it is imperative to solve several technical and methodological problems. First of all, a universal sorbent with high sorption capacity and mechanical durability must be developed. The problem of intravenous infusions is very important--it is not only one of the principal ones in sorption therapy, but in administering anesthesia, perfusions and in surgical interventions.

One solution to this problem is the use of disposable systems filled with drugs or blood substitutes before the flight, on the ground. However, this involves certain difficulties, due to the limited shelf life of some drugs and blood substitutes, as well as the need for a large quantity of disposable units. It is preferable to develop systems and devices that permit reliable separation of fluid from gas in weightlessness. As shown by preliminary studies, this is attained with the use of gas-permeable film or centrifugal separators.

Development of a system of emergency care presents a special problem, when life-threatening states develop during self-contained existence outside an orbital spacecraft, i.e., in a spacesuit, when engaged in extravehicular activity or working on another planet. Scientific work in this direction is based on principles of automation of life-saving measures in accordance with programs prepared in advance. The triggering mechanism of such factors should be the programming of the most probable life-endangering disturbances in cardiac function, respiration and critical disorders referable to vascular tonus.

Thus, even in this general survey of the problem of emergency medical aid during manned spaceflights, the breadth of scientific research and special technical projects necessary to develop a system of specialized care in emergency situations during manned spaceflights is obvious. At the same time, in spite of the difficulty of technical solutions of most of the problems mentioned, the directions of scientific research in this area are distinctly delineated.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

UDC: 629.78:612.13

REGIONAL HEMODYNAMIC CHANGES AFTER SPACEFLIGHTS LASTING UP TO EIGHT DAYS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 17 Nov 81) pp 12-17

[Article by T. D. Vasil'yeva, Kh. Kh. Yarullin and V. I. Zhuyko]

[English abstract from source] Before and after space missions of up to 8 days in duration 14 cosmonauts were exposed to rheographic examinations to measure the pulse blood filling, tone and elasticity of cerebral vessels (in the frontal-mastoidal and bimastoidal leads), right lung and right leg vessels during tilt tests. Postflight examinations demonstrated distinct changes in the cerebral, pulmonary and peripheral circulation, thus indicating cardiovascular deconditioning. The greatest changes were seen in the tone of arteries, arterioles and veins of the brain hemispheres, vertebro-basilar system and the leg. The changes were reversible, requiring no special correction. The changes in different vascular compartments returned to normal in a nonuniform manner: hemodynamic parameters of the lung and leg returned to the preflight level by R+3, whereas those of the brain by R+14.

[Text] It is known that decline of orthostatic stability (OS) has always been observed in cosmonauts after missions due to deconditoning of the cardiovascular system [1-6]. Several researchers mention, among the causes of diminished OS, deconditioning of the vascular component [3, 6]. For this reason, it was interesting to summarize the results of studies of cosmonauts' regional hemodynamics during orthostatic tests (OT), as well as changes in parameters of vessels of different regions occurring as a result of spaceflights and to trace the dynamics of recovery thereof.

Methods

We conducted a rheographic study of blood filling, tonus and elasticity of cerebral vessels (in frontomastoid and bimastoid leads), right lung and right lower leg during OT in 14 cosmonauts before and after spaceflights lasting up to 8 days. OT were performed once before the flight, and after the flight--on the day they landed, 3d and 14th days. OT consisted of having the cosmonauts stand passively on a turntable at an angle of 70° for 10 min. The

rheogram was recorded on a bipolar 4 RG 1M rheograph using an 8-channel electroencephalograph, and this was done before the test, with the subjects in horizontal position, then in the 1st, 3d, 5th, 7th, 9th min in vertical position and 1st, 3d 5th min of horizontal position.

We studied the following parameters: maximum amplitude of rheographic wave (A) in ohms, which reflects pulsed filling of vessels of the region examined; ratio of duration of anacrotic phase of rheogram to duration of cardiac cycle (α/T), as a percentage reflecting mainly the tonus and elasticity of large and medium caliber arteries; ratio of height of incisura to maximum amplitude of rheogram--dicrotic index (DCI) and ratio of dicrotic elevation to maximum amplitude--diastolic index (DSI), reflecting arteriolar and venous tonus, respectively. All of the obtained data were submitted to statistical processing.

Results and Discussion

Endurance of OT before the flight was rated as good in all cosmonauts.

Before the flight, in the 1st min of vertical position, the subject presented a 25% decrease ($p<0.05$) in pulsed filling of the right hemisphere, which gradually increased from the 3d min on, but still was 15% lower than the background value in the 9th min. When the cosmonaut was moved to horizontal position, pulsed filling increased, exceeding the base value by 13% in the 1st min in this position. Thereafter, this parameter gradually declined to the background level (Figure 1a).

In the OT done 4-6 h after landing (0 day), the changes in pulsed filling of the right hemisphere with the cosmonaut in vertical position were analogous; however, when he changed to horizontal position it increased more drastically than before the flight, exceeding the base level by 34% ($p<0.01$). There was development of moderate reactive cerebral hyperemia, which had been negligible before the flight.

On the 3d postlanding day, with the OT there was more marked decline, by 38%, in pulsed filling of the right hemisphere than on 0 day ($p<0.05$). On the 14th day, we demonstrated even greater decline in pulsed filling during the test, and it reached 43% ($p<0.05$). In the OT before the flight α/T of the right hemisphere decreased by 34% ($p<0.05$). During the recovery period in horizontal position, it increased appreciably and was 12% greater than the pretest level (Figure 1b). On 0 day, α/T both at rest before the test and in erect position exceeded significantly the preflight values ($p<0.05$). On the 3d postflight day, α/T was above the preflight value only with the subjects in horizontal position before and after OT, and during the test the absolute values and dynamics thereof did not differ from preflight findings.

REG DCI of the hemisphere during the preflight OT decreased by 25% ($p<0.01$) in the 1st min, remaining on this level thereafter, to the end of the test (Figure 1c). On the day of landing REG DCI during the OT diminished more significantly--by 37% ($p<0.001$). This parameter recovered faster, within the first min in horizontal position. DCI dynamics did not differ reliably from preflight findings on the 3d and 14th postflight days.

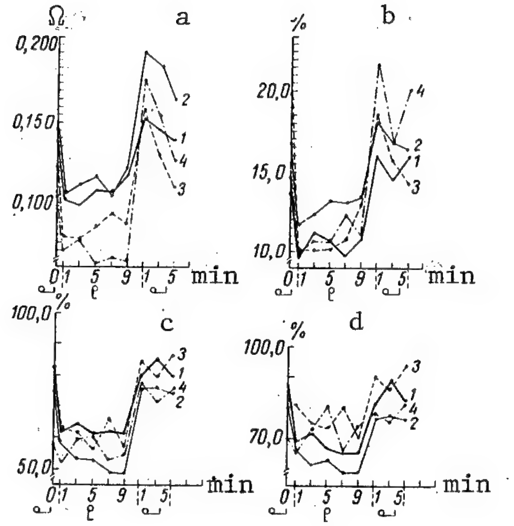

Figure 1.
Changes in pulsed filling (a), tonus of arteries with large and medium caliber (b), dicrotic index (c) and diastolic index (d) of the right hemisphere during orthostatic test

Here and in Figures 2-4:
1) preflight
2) landing day
3) 3d postflight day
4) 14th postflight day
X-axis, time of test (min);
y-axis, values of parameters

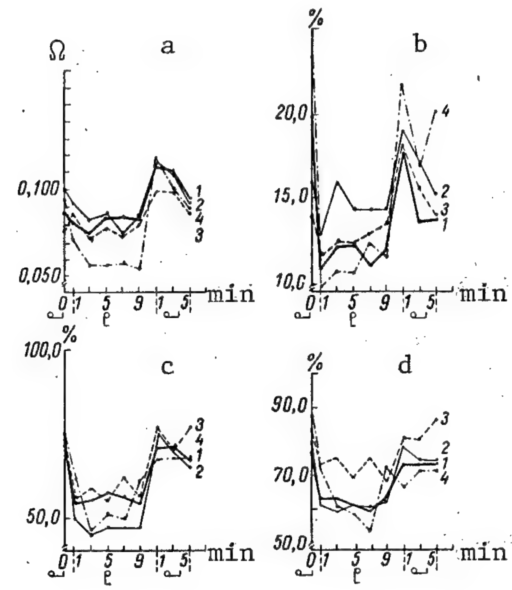

Figure 2.
Changes in hemodynamic parameters of vertebrobasilar system during OT

Preflight DSI during the first min of the OT (Figure 1d) decreased by 22% ($p<0.01$), gradually declining (by 25%; $p<0.01$) by the 9th min. On 0 day, the dynamics of DSI during the OT did not differ from preflight findings; however, both during the test and in the recovery period, the mean values of parameters of venous tonus were 15% lower than preflight. Venous tonus of the right hemisphere increased on the 3d and 14th postflight days, and these parameters were higher than before the flight ($p<0.05$).

The above-described dynamics of amplitude, α/T and DCI of cerebral hemispheres during the OT were indicative of significant decline of arterial and venous tonus, as well as filling with blood after the flight. This was apparently attributable to weakening of mechanisms of regulating vascular tonus, particularly that of arterioles. The decrease in tonus of intracranial veins after the flights (manifested by significant decline of DSI at rest) was also instrumental in worsening conditions for circulation of blood and thereby blood supply to the brain as well [4, 5].

Studies of hemodynamics of the vertebrobasilar system before the flight, during the OT, revealed less marked (15%) decrease in pulsed filling than in the pool of the internal carotid. In the 1st min in horizontal position after the

test, the cosmonauts showed significant increase, by 30% ($p<0.1$), in pulsed filling. This reactive hyperemia disappeared by the 5th min (Figure 2a). On 0 day and on R+3, the dynamics of this parameter were analogous. The decline of A demonstrated on the 14th day was unreliable.

Parameter α/T of the vertebrobasilar system before and at different periods after the flight decreased by 24-33% during the OT ($p<0.05$, Figure 2b).

The DCI on the bimastoid REG during the preflight OT (Figure 2c) decreased by 22% and on 0 day by 37% ($p<0.01$). As early as the 3d postflight day, the dynamics of DCI of the vertebrobasilar system during the OT approached preflight data.

Preflight DSI during the OT was identical to changes in DCI (Figure 2d). Reliable changes in venous tonus were demonstrable during OT only on the 3d postflight day, when DSI exceeded preflight values by 27% ($p<0.05$) with the subjects in horizontal position before the test and in erect position during the test.

As we see, during the OT, there was gradual and considerably less marked decrease of tonus and pulsed filling in the vertebrobasilar system on landing day than in the pool of the internal carotid, which was indicative of retention of the shift of the zone of hemodynamic equilibrium between carotid and vertebrobasilar systems in the direction of the former [7, 8], which is inherent in people up to 45 years of age, as well as less weakening of mechanisms of regulation of hemodynamics of this pool.

During the preflight OT, we observed a significant decrease in pulsed filling of the lung, and it was 49% lower by the 3d min of the test than in the background (Figure 3a). When the subject moved to horizontal position, this parameter rapidly reverted to the background value. The dynamics of A of the lung during OT on 0 day were analogous to preflight findings; however, the absolute values of the parameters were considerably lower than before the flight ($p<0.05$). During the recovery period in horizontal position, there was more significant rise of this parameter than preflight, and it exceeded the base preflight value by 30% in the 1st min and by 19% in the 5th min ($p<0.1$). The dynamics of pulsed filling during the OT showed virtually no difference from preflight findings on the 3d and 14th postflight days.

Preflight α/T of the lung during the OT diminished by 20% (Figure 3b), and on the day of landing by 29% ($p<0.1$). The dynamics of α/T on the 3d and 14th postflight days resembled preflight values.

DCI of the lung during the preflight OT increased by an average of 21% ($p<0.1$). After the test, we observed drastic decline of DCI, by 30% ($p<0.01$); by the 5th min, DCI reverted to the initial base level (Figure 3c). On 0 day, there was gradual increase of this parameter toward the end of the test and less drastic decline after it. The changes on the 3d and 14th days were unreliable.

The changes in RG DSI of the lung during the OT were insignificant.

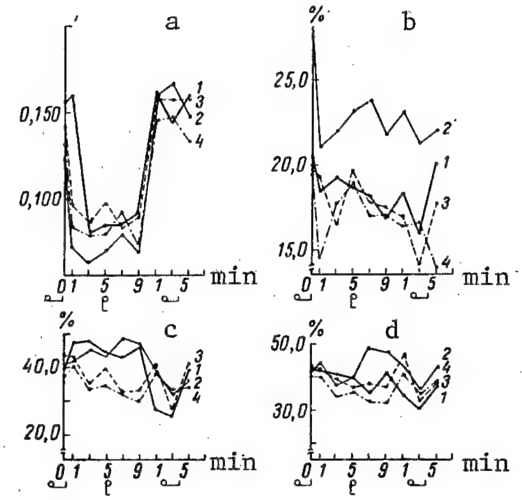

Figure 3.
Changes in hemodynamic parameters of the lung during OT

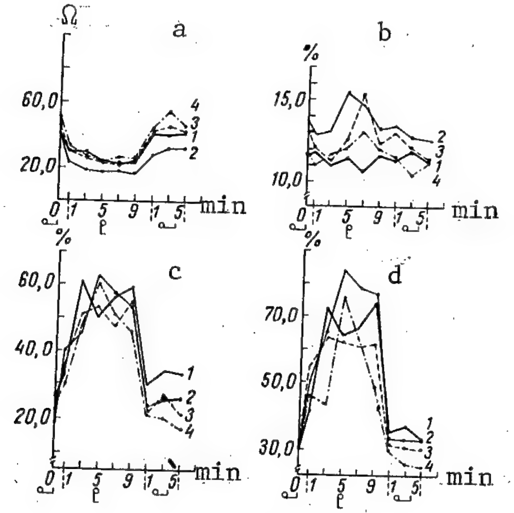

Figure 4.
Changes in hemodynamic parameters of the lower leg during OT

Pulsed delivery of blood to the lower leg during the preflight OT (Figure 4a) decreased by 48% ($p<0.001$), which was apparently a reflection of decreased difference between influx and efflux of blood, i.e., development of hemostasis in the leg. After the subjects changed to horizontal position, A increased to background level. On 0 day, there was a decline of this parameter (by 61%, $p<0.01$). The dynamics of this parameter on the 3d and 14th postflight days resembled preflight findings; α/T of the leg changed insignificantly before and at different times after the flight, during the OT; however, absolute values thereof were higher after the flight, both before and during the test. The values of α/T gradually declined and by the 14th day showed virtually no difference from preflight data.

There were significant changes in parameters of tonus of arterioles (DCI) and veins (DSI) of the leg. During the preflight OT, DCI increased, exceeding base values by 136% ($p<0.1$, Figure 4c). This was apparently a reflection of increased compensatory tension of the walls of arterioles and small arteries due to an increased influx of blood during the test. Immediately after the subjects returned to horizontal position, the values of DCI decreased, being insignificantly higher than pretest values. After landing, on 0 day, mean parameter of arteriolar tonus at rest in horizontal position was 30% less than preflight ($p<0.1$). It is quite probable that the observed decline of arteriolar tonus in the leg after the flight led to significantly greater change in this parameter during the OT. Thus, in the 5th min of the test, DCI was 210% above the pretest level ($p<0.01$), i.e., worsening of tonic properties of arterial vessels of the leg after the flights elicited greater tension thereof with intensified influx of blood in passive erect position.

Thereafter, we observed gradual normalization of parameters of arteriolar tonus between the 3d and 14th days, both at rest and in response to orthostatic position.

Analogous dynamics were demonstrable with regard to the parameter of tonus of crural veins (Figure 4d). DSI, i.e., filling of veins, increased by 138% during the OT ($p<0.01$). After the OT this parameter returned to the base level within 5 min. On landing day, DSI increased by 183% during the OT and was reliably greater than preflight values throughout the test ($p<0.01$), i.e., there was more marked venous stasis in the leg. However, by the 3d day the reaction of crural veins to the orthostatic test improved significantly and did not differ reliably from the preflight one.

Thus, during the postflight OT there was more significant decrease in filling of the arterial system of the leg, against a background of drastic increase in filling and tonus of veins, as well as compensatory increase in arterial and arteriolar tonus.

In spite of the short duration of flights (up to 8 days), all 14 cosmonauts presented marked changes in cerebral, pulmonary and peripheral circulation. The dynamics of rheographic indicators of the condition of vessels in the regions studied during the OT on the day of landing were indicative of some deconditioning of the vascular system for earth's gravity, which occurred as a result of spaceflights. In the opinion of a number of authors (9, 10], exclusion of hydrostatic blood pressure from circulatory dynamics, which is observed in weightlessness, may decondition the mechanisms of adaptation of the cardiovascular system which are responsible for maintaining circulatory homeostasis when man is in erect position. The parameters of tonus and elasticity of arteries, arterioles and veins of the cerebral hemispheres, vertebrobasilar system and lower leg underwent the greatest changes. The observed changes were of a reversible functional nature, and they did not require special correction. There was uneven restoration of postural changes in hemodynamics of the different vascular regions. The parameters of lung and crural hemodynamics were close to preflight values on the 3d postflight day, whereas those of the cerebral hemispheres approached them by the 14th day of the readaptation period.

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UDC: 629.78:612.766.1

EFFECT OF OPTOKINETIC STIMULATION ON OPERATOR'S FUNCTIONAL STATE AND PROFESSIONAL WORK CAPACITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 30 Jun 81) pp 17-20

[Article by L. N. Kornilova, S. L. Kravchenko, L. D. Smirichevskiy and A. A. Belonogov]

[English abstract from source] The effect of optokinetic noise on the clinicophysiological and professional parameters of a trained operator is discussed. The pattern and level of changes in the parameters are shown to depend on the initial sensitivity to optokinetic stimulation. It is recommended that expertise measurements be performed of optokinetic stimulation tolerance as well as training sessions with the operator exposed to optokinetic stimulation.

[Text] In recent years, information gained from space missions by means of visual observations is acquiring increasing importance to science and the national economy. When performing this type of work, optokinetic stimulation in the form of constant shift at a specific angular velocity of objects on earth and other visible objects affects the operator, in addition to the set of flight factors.

The studies of American authors [1-4], as well as the reports of cosmonauts, have indicated that an optokinetic stimulus could impair tracking, whereas long-term exposure to it elicits unpleasant sensations similar to symptoms of motion sickness.

Our objective here was to investigate the effects of optokinetic stimuli on the functional state of an operator and his professional work capacity. In addition, it was interesting to determine whether or not there are any distinctive features in professional performance and physiological reactions of the operator to optokinetic stimulation as related to initial background sensitivity to vestibular and optokinetic stimuli.

Methods

A total of 16 men 25 to 45 years of age, who had passed through the expert medical commission and been deemed essentially healthy (otorhinolaryngologists, neuropathologists and ophthalmologists were among those who examined them) participated in our studies.

Control studies were pursued before we started to work with them in order to determine individual sensitivity to optokinetic and vestibular stimuli. Vestibular stability (vestibulovegetative) was determined according endurance of the test in [5] and optokinetic stability according to endurance of optokinetic stimulation (OKS) which elicited a pseudo-Coriolis rocking [motion] effect. The optokinetic stimulus was delivered by means of a special drum, which projected on a circular screen black and white bands that moved at an angular velocity of 60°/s at an angle of 45° to the operator's longitudinal axis. This rate and stimulus were chosen on the basis of the results of preliminary tests to determine severity of autonomic and sensory reactions, as well as integrity of tracking function of the eyes.

During the studies, we recorded pulse rate (PR) on the electrocardiogram (EKG), arterial pressure (AP) by the tachooscillographic method, tension index (TI) and autonomic heart rate index (AHR) from the cardiointervalogram (CIG) according to R. M. Bayevskiy [6], autonomic reactions (AR) according to Khilov, optokinetic nystagmus by the electronystagmographic method, accuracy of perception of gravity vertical against a background of optokinetic interference and reference field during the experiment, as well as in the background and aftereffect periods.

After the background studies, all of the subjects were taught elements of regular operator work. They had 6 cycles of practice sessions in a small isolation chamber, on a mock-up of an operator's console, which was in a housing installed in the standard position. Training proceeded in a complicated information environment and with shortage of time; it was associated with uneven emotional tension.

We recorded the following clinical physiological parameters during training in operator work: PR, AP, TI, AHR, AR and accuracy of perception of spatial coordinates. Accuracy of manual guidance of the object, as well as speed and accuracy of performing other work on the standard [according to regulations] program served as the parameter of operator performance.

After acquiring stable professional skills, all of the subjects were submitted to optokinetic stimulation for 30 min. First, the operators were submitted to the separate effect of optokinetic stimulation by the above-described method for 10 min; then they began to execute the learned program of operator work against the background of continuing optokinetic interference, in the form of bands running over the console and walls of the chamber. After stopping the optokinetic interference, the subjects repeated operator work on an identical program.

Results and Discussion

Determination of level of vestibular and optokinetic stability enabled us to divide all of the subjects into the following groups: "stable" and "unstable" with regard to either stimulus. Subjects who endured the vestibular test and OKS for 10 min with 0 AR, with relative stability of recorded clinico-physiological parameters were classified in the "stable" group; those with grade I or I-II AR and marked variability of clinicophysiological parameters were put in the "unstable" group. Thus, there were five people in the "stable" group for endurance of the vestibular test and nine for endurance of OKS. Table 1 lists data on comparative endurance of vestibular and optokinetic stimuli. A comparison of endurance of vestibular and optokinetic stimuli revealed (see Table 1) that stability coincided in eight cases (three men "resistant" to OKS and vestibular stimuli, five not resistant to both stimuli). In the other operators, endurance of the two stimuli did not coincide (two were resistant to vestibular stimuli but not to OKS, while the reverse was true for six others).

Table 1.
Endurance of vestibular and optokinetic sitmuli by subjects

Parameter	VI	VS	OKS_i	OKS_s
VS	0	5	2	3
VI	11	0	5	6
OKS_s	6	3	0	9
OKS_i	5	2	7	0

Key for this and Table 2:
VS) vestibular stability
VI) vestibular instability
OKS_s) optokinetic stability
OKS_i) optokinetic instability

Table 2.
Parameters of physiological reactions and professional performance of trained operators differing in level of vestibular and optokinetic stability

Parameter	Clinicophys. parameters				Manual guidance parameters			
	ΔPR	ΔAP_{max}/ΔAP_{min}	ΔTI	ΔAHR	ϕ degr.	θ, g	γ, g	Q, s
VS	4	5/0	21	1	2,3	2,1	1,0	9,5
VI	4	5/0	10	0	2,2	2,1	2,2	10,2
OKS_s	4	0/0	7	0	2,4	2,5	2,0	13,4
OKS_i	6	5/5	18	1	2,2	1,7	2,0	8,6

Key:
ϕ, θ, γ) magnitude of error in course, banking and pitching, respectively
Q) time expended by working body [?]
Δ) scatter of fluctuations of parameters during professional activity

Thus, in the background studies we demonstrated selective sensitivity of operators to vestibular and optokinetic stimuli. Analysis of the results was made with consideration of the demonstrated group differences.

The nature and dynamics of the training process in learning operator work were unrelated to differences in levels of vestibular and optokinetic stability. All of the subjects attained stable skills in performing the selected program of operator work with virtually the same parameters of the tested body reactions (Table 2).

Analysis of the results of submitting operators to OKS revealed that in all subjects, with the exception of the optokinetically "stable" ones, there was impairment of professional performance against a background of optokinetic noise and particularly in the OKS aftereffect period (Figure 1). Thus, the error of visual manual guidance of the object (for example, course) increased from 2 to 3.5° in the optokinetically "unstable" group in the presence of noise and to 5° in the OKS aftereffect period. Two operators in this group could not cope with the program of manual guidance of the object and were excused from the work, and one of them had a high level of vestibular stability. In all subjects sensitive to OKS, including two with vestibular stability put in this group, optokinetic stimulation elicited symptoms of motion sickness. They were manifested by vertigo, pallor of the face, perspiration, change in HR, AP to 150/100 (in some cases) in the last minutes of OKS.

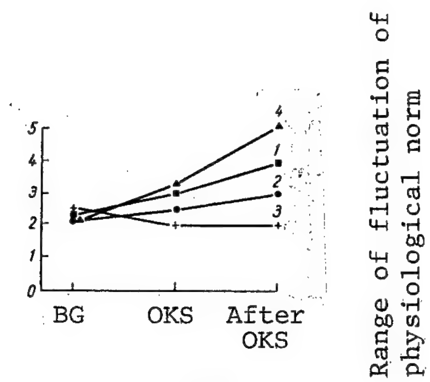

Figure 1.
Parameters of manual guidance of object (bearing, in degrees) in subjects differing in optokinetic and vestibular stability in the presence of optokinetic noise.
Here and in Figure 2:
1) vestibularly stable
2) vestibularly unstable
3) optokinetically stable
4) optokinetically unstable
BG) background

Group differences in operator reactions to OKS during professional work were particularly manifest in parameters of TI of cardiac function according to cardiointervalographic data (Figure 2). In all groups, with the exception of the optokinetically "unstable" ones, there was increase in TI, characterizing a strain on regulatory mechanisms and indicating that the body was reacting adequately to the stimulus [6]. In the "unstable" group for OKS, unlike the others, we observed a decline of TI at the time of stimulation. This inadequate reaction can apparently be interpreted as stress of regulatory systems in the OKS "unstable" operators when following the program of manual guidance of an object in the presence of optokinetic noise.

Our study of perception of spatial coordinates during exposure to OKS failed to demonstrate group differences: an increase in error (from 0.5° to 1.9° with interference and up to 2.5° in the OKS aftereffect period) was observed in subjects of all groups. However, the preliminary test of accuracy of perception of gravity vertical against the background of stationary tilted visual field--test frame and rod [7]--enabled us to establish that this test depends on initial resistance to OKS and vestibular stimuli (0.7° in the group with vestibular stability; 2.2° for those with vestibular instability; 1.0° for thos with optokinetic stability; 2.5° for those with optokinetic instability).

The results of our studies, which conform with the data of American authors, revealed that the optokinetic stimulus, which leads to impairment of operator activity and, in particular, spatial orientation may be significant to the

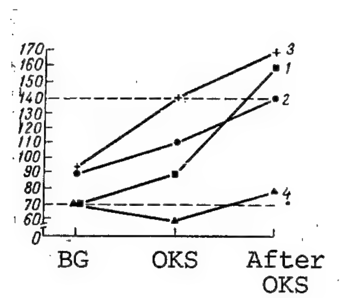

Figure 2.
Dynamics of tension index in the course of manual guidance of object against the background of optokinetic stimulation in subjects differing in level of optokinetic and vestibular stability

impaired orderliness of analyzer function, whereas prolonged presence thereof in the case of subjects who are optokinetically "unstable" elicits development of symptoms of motion sickness.

The obtained data warrant the assumption that the optokinetic factor is involved in formation of "sensory conflict" during spaceflights, and they are indicative of the desirability of conducting operator training against a background of optokinetic interference, as well as of expert testing for resistance to OKS.

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UDC: 629.78:616.831-005.98-085.254.1

DEHYDRATION THERAPY FOR SUBJECTS EXPOSED TO SIMULATED SPACEFLIGHT CONDITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 8 Oct 81) pp 20-24

[Article by L. L. Stazhadze, T. M. Demidova, Zh. M. Kudryashova and L. G. Repenkova]

[English abstract from source] The effect of intravenous injection of 20% mannitol in a dose of 1 g per kg body weight at a rate of 5 mℓ/min on the central circulation and cardiac contractile function was investigated. The infusions were performed to 18 healthy male volunteers, who participated in a head-down tilt test at -8°, during the control period, on days 3, 7 and 14 of bed rest, and during the recovery. It was found that prolonged osmotherapy produced a clinically distinct dehydration effect without influencing central circulation. The therapy also led to positive cardiodynamics, which was indicative of a decrease of the heart unproductive work and an improvement of left ventricle contractile function.

[Text] Edema and swelling of the brain, as a universal nonspecific reaction to various deleterious factors, is a complication of many acute emergency states [1, 2]. It is important to stress that elevation of systemic venous pressure has a much stronger effect on development of cerebral edema than elevation of arterial pressure. In the literature, the term, "pre-edema" is generally used to refer to a state of the brain, when changes have already developed causing onset of edema [3]. In weightlessness, like in antiorthostatic [head tilted down] hypokinesia, plethora has been observed of the vascular network of the brain with signs of diminished venous efflux, increased filling with blood and pressure in jugular veins [4, 5], and, even with adequately compensated venous stasis, this is manifested by puffiness of the face, palpebral edema, injection of scleral vessels, as well as by subjective signs--sensation of flushed head, neck, pulsation and heaviness of the head, congested nose [6, 7]. In the presence of such orthostatic disturbances associated with acute emergency states, the probability of development of cerebral edema and swelling increases significantly.

In the light of the foregoing, it is important to stress that, as compared to this state on the ground, edema and swelling of the brain against a background

of redistribution of body fluids may develop in response to a relatively lesser magnitude of the deleterious factor [13].

Osmotherapy is a mandatory component of resuscitation measures to control cerebral edema and swelling; in turn, it has an appreciable influence on hemodynamics [8, 9, 14]. In view of the alteration of cardiovascular function in weightlessness, our objective was to elaborate an osmotherapy regimen that would have a marked dehydration effect with minimal adverse effects on hemodynamics.

Methods

The studies were conducted on 18 essentially healthy men ranging in age from 26 to 38 years, who were submitted to antiorthostatic hypokinesia (AOH) with the head end of the bed tilted down at an angle of -8° for 7 and 14 days. We administered intravenous drip infusion of 20% mannitol at the rate of 1 g/kg body weight in the background period before hypokinesia, on the 3d, 7th and 14th days of AOH and in the acute recovery period after termination thereof. In the preceding series of studies mannitol infusions were given for 20 min in a dosage of 1 g/kg. In view of the demonstrated hemodynamic changes associated with rapid infusion of this agent, in this study the mean rate of infusion constituted 5 mℓ/min. Overall duration of infusion ranged from 65 to 100 min.

We used polycardiography to assess central hemodynamics and myocardial contractile function. Polycardiograms were recorded on an 8-channel Mingograph 82. Cardiac minute volume (MV), cardiac index (CI), stroke index (SI), stroke volume (SV) and total peripheral resistance (TPR) were calculated by the method of integral rheography according to M. I. Tishchenko [11]. Phase analysis of the cardiac cycle was performed according to V. L. Karpman [12]. The infusions were given with monitoring of arterial pressure (AP), heart rate (HR) and parameters of electrolyte composition of blood.

We made a complex study of retinal circulation. We determined the pressure in the central retinal artery (PCRA), caliber of central retinal artery and vein (CRA and CRV) and intraocular pressure (IOP).

We evaluated the diuretic effect. The above tests were performed before starting the infusion, immediately after terminating it and 1.5 h later.

The data were submitted to statistical processing using nonparametric paired critera for related and independent groups, as well as the parametric criterion of Student.

Results and Discussion

Table 1 lists the results of examining the parameters of central hemodynamics. We found merely a tendency toward increase in mean MV by the 7th day of AOH and in the acute stage of the recovery period at the time of terminating the infusion, by 18 and 10%, respectively, in relation to base levels. MV was

still above the base value 1.5 h after terminating the infusion, on the 7th day, whereas in the acute recovery period (ARP) it was already 17.5% less than the base level. When the infusion was given on the 14th day, MV remained virtually unchanged. There was a tendency toward decline of mean MV and subsequent restoration at 1.5 h of the aftereffect period under the influence of infusion given prior to AOH. These changes were not significant, and they were statistically unreliable.

Table 1. Parameters of central hemodynamics with infusion of 20% mannitol at different stages of AOH (M±m)

AOH stage	Infusion period	MV, ℓ/min	CI, ℓ/min·m^2	SI, ℓ/m^2	SV, ℓ	TPR, dyne·s·cm^{-5}
Background	Before start	11,2±0,87	5,7±0,58	0,09±0,004	0,19±0,04	681,5±61,1
	After end	10,6±0,64	5,3±0,38	0,08±0,005	0,16±0,01	698,8±45,9
	After 1.5 h	11,3±1,04	4,8±0,59	0,07±0,022	0,13±0,02	841,2±104,5
3d day	Before start	9,1±1,1	5,0±0,94	0,08±0,01	0,16±0,01	754,6±96,4
	After end	8,4±0,85	4,5±0,44	0,07±0,009	0,13±0,02	784,0±55,8
	After 1.5 h	7,3±0,51*	3,9±0,34	0,07±0,003	0,14±0,01	897,2±104,9
7th day	Before start	7,9±1,4	4,1±0,47	0,06±0,004	0,12±0,02	1026,8±172,4
	After end	9,3±0,49	4,9±0,3	0,07±0,01	0,15±0,09	789,8±51,5
	After 1.5 h	8,7±1,21	4,6±0,7	0,07±0,01	0,13±0,01	879,9±79,5
14th day	Before start	7,9±0,44	4,1±0,27	0,07±0,004	0,13±0,01	942,6±88,8
	After end	7,8±0,83	3,9±0,28	0,06±0,004	0,12±0,01	938,4±97,4
	After 1.5 h	7,4±0,49	3,9±0,19	0,07±0,008	0,14±0,02	921,3±35,6
Acute recovery period	Before start	7,8±0,48	4,4±0,78	0,06±0,009	0,12±0,02	967,4±203,4
	After end	8,6±0,63	4,0±0,54	0,06±0,004	0,11±0,001	1047,7±111,0
	After 1.5 h	6,4±0,35	3,8±0,05	0,06±0,005	0,11±0,002	1081,5±12,5

Here and in Tables 2 and 3:
*Reliable difference from background value ($P<0.05$) according to Wilcoxson criterion.

A statistically reliable decline of MV by 19.8% was demonstrable when the infusion was given on the 3d day of hypokinesia 1.5 h after termination of infusion ($P<0.05$). At the same stage, we observed the most marked diuretic effect. The rate of diuresis was particularly intensive during the first hours after infusion of mannitol, whereas 24-h diuresis was double the control level. Systemic AP regardless of stage of AOH, as well as in the background period, presented a tendency toward transient elevation by an average of 10 mm Hg at the first stage of infusion, which corresponded to the hypervolemic stage of diuretic effect [9]. AP then began to decline somewhat and was below base values by an average of 10-15 mm Hg at the end of the infusion. Since AP and HR did not change appreciably, we failed to demonstrate reliable changes in the other estimated hemodynamic parameters--CI, SI, SV and TPR.

Thus, there were no appreciable changes in central hemodynamic parameters under the influence of intravenous infusion of 20% mannitol at the rate of 5 mℓ/min.

We should mention the decline of MV at 1.5 h of the aftereffect period of acute adaptation to hypokinesia (3d day of AOH).

Table 2. Parameters of regional circulation with infusion of 20% mannitol at different stages of AOH (M±m)

Period of AOH	Infusion period	PCRA, mm Hg	CRA, μm	CRV, μm	IOP, mm Hg
Background	Before start	38±0,8	58±1,4	147±4,3	20±0,1
	After end	36±1,2*	58±1,8	147±3,3	16,5±0,3*
	After 1.5 h	32±1,4*	43,5±2,6*	132±1,8*	20±1,1
3d day	Before start	41±2,1	67±1,8	160±5,0	18±0,4
	After end	36±1,8*	67±2,4	145±3,1*	15,1±0,7*
	After 1.5 h	27±0,9*	48±2,5*	135±4,0*	16±0,2*
7th and 14th days	Before start	36±0,6	71,5±1,2	162±4,3	19±0,1
	After end	33±1,4*	64,7±0,9*	147±2,1*	17±0,1*
	After 1.5 h	31±0,8*	61±2,3*	136±2,4*	18,3±1,4
Acute recovery period	Before start	36±0,1	71,5±1,4	157±1,4	23±1,4
	After end	34±0,7*	63±1,1*	143±1,8*	15±0,7*
	After 1.5 h	25±1,1*	55±2,3*	136±2,5*	17±0,6*

At the time of termination of infusion, which was given during AOH and in the ARP, there was reliable decrease in PCRA, CRV and IOP, which preceded the diuretic effect proper. The substantial decline of the above parameters of retinal circulation apparently confirms the fact that, under the influence of hypertonic mannitol solution, the brain is dehydrated more actively than other organs and tissues [8, 9]. CRA remained stable on the 3d day of AOH, decreasing significantly at 1.5 h of the aftereffect period ($P<0.05$). All of the above parameters remained considerably below base levels 1.5 h after terminating the infusion, and this was apparently related to continuation of the process of diverting fluid from brain tissues by virtue of the remaining osmotic gradient between plasma and the brain [8-10]. After the infusion given in the background period of AOH, CRA and CRV remained stable, decreasing only at 1.5 h of the aftereffect period. IOP was the most labile parameter, regardless of period when the infusion was given.

Thus, the dynamics of parameters of retinal circulation were indicative of a marked cerebral dehydration effect of mannitol as we administered it. There was no retinal vascular reaction (CRA and CRV) at the time the infusion was terminated in the background period; the effect occurred much later than when the infusion was given at other stages of AOH and the ARP. Retinal vessels demonstrated a distinctive reaction on the 3d day of AOH: the caliber of retinal arteries did not change, in spite of drop of PCRA, and it is only 1.5 h after termination of infusion that CRA also diminished.

The presence of some difference in dynamics of MV and parameters of retinal circulation on the 3d day of hypokinesia under the influence of mannitol was apparently attributable to the acute process of adaptation to hypokinesia, which occurred at this time, with some changes in central and cerebral hemodynamics concomitant to this period.

Table 2 lists the parameters of retinal calculation.

Analysis of phase structure of myocardial contractile function (Table 3) at the time of termination of infusion (3d day) revealed a reliable decrease in tension time due to decrease in isometric contraction phase, reliable ($P<0.05$) decline of mechanical (on 7th day) and overall systole (14th day). The intrasystolic index increased reliably on the 3d day, whereas a reliable decline ($P<0.05$) of index of myocardial tension was noted in the ARP. When the infusion was given in the ARP, there was a reliable ($P<0.05$) increase in expulsion period. During the aftereffect period, after 1.5 h, the parameters of the phase of isometric contraction and mechanical systole were reliably lower than base values. When the infusion was given in the background period, before starting AOH, there was a reliable decrease in tension period, phase of isometric contraction, mechanical systole, myocardial tension index, whereas the intrasystolic index rose ($P<0.05$).

Table 3. Phases of cardiac contractile function with infusion of 20% mannitol at different stages of AOH (M±m)

Parameter	Perfusion period	Period of hypokinesia				
		Background	3d day	7th day	14th day	ARP
Tension period, s	1	0,13±0,006	0,13±0,005	0,13±0,01	0,13±0,005	0,12±0,004
	2	0,11±0,006*	0,11±0,01*	0,12±0,04	0,12±0,005	0,11±0,006
	3	0,12±0,008	0,13±0,007	0,12±0,008	0,13±0,007	0,13±0,02
Contraction phase: asynchronous	1	0,05±0,004	0,05±0,003	0,06±0,004	0,05±0,003	0,05±0,006
	2	0,05±0,003	0,05±0,02	0,06±0,001	0,06±0,002	0,05±0,005
	3	0,06±0,01	0,05±0,007	0,06±0,004	0,06±0,004	0,06±0,02
isometric	1	0,08±0,008	0,08±0,005	0,07±0,007	0,08±0,004	0,07±0,005
	2	0,06±0,006*	0,06±0,004*	0,06±0,007	0,06±0,007*	0,06±0,007
	3	0,07±0,004	0,07±0,007*	0,06±0,004	0,07±0,005	0,06±0,01
Expulsion period, s	1	0,27±0,01	0,27±0,009	0,26±0,007	0,26±0,005	0,25±0,04
	2	0,27±0,05	0,27±0,009	0,27±0,007	0,26±0,009	0,27±0,006*
	3	0,24±0,03	0,27±0,006	0,27±0,01	0,27±0,04	0,26±0,01
Systole, mechanical, s	1	0,35±0,006	0,36±0,01	0,33±0,001	0,34±0,007	0,31±0,008
	2	0,33±0,01*	0,33±0,009	0,31±0,006*	0,32±0,01	0,33±0,005
	3	0,30±0,02	0,34±0,006*	0,32+0,02	0,34±0,09	0,32±0,02
total, s	1	0,39±0,006	0,40±0,009	0,39±0,003	0,39±0,006	0,37±0,006
	2	0,39±0,01	0,38±0,009	0,37±0,006	0,37±0,007*	0,38±0,006
	3	0,36±0,03	0,39±0,007	0,38±0,01	0,40±0,06	0,38±0,02
Intrasystolic index, %	1	76,7±2,45	77,0±1,42	81,8±3,29	78,4±0,44	78,6±1,32
	2	81,4±1,93*	81,8±0,09*	79,9±4,61	81,2±1,91	82,5±2,18
	3	78,4±2,86	79,0±2,05	82,2±0,98	79,3±1,34	80,5±3,15
Myocardial tension index, %	1	32,5±1,61	32,4±1,32	30,7±2,72	32,9±1,16	32,7±1,03
	2	29,6±1,57*	29,6±2,83	31,9±1,66	31,0±1,74	29,0±1,22*
	3	34,2±2,65	31,7±1,48	30,7±1,43	32,2±1,30	32,8±15,3

Key: 1) before starting infusion
2) period after end of infusion
3) 1.5 h after end of infusion

The above-described dynamics of cardiac function can be evaluated on the whole as favorable, indicating a decrease in unproductive myocardial function and improved contractile function of the left ventricle. Several authors [15-19]

have described improvement of coronary blood flow and cardiac function in the presence of acute myocardial ischemia under the influence of mannitol infusions, as well as the property of this agent to reduce infarction zone in the presence of coronary occlusion. In particular, it was reported [20] that hypertonic mannitol solution can neutralize the subsequent depressive effect on propanolol on the myocardium, without concomitant increase in myocardial oxygen requirement; the EKG showed no myocardial hypoxia. The positive effect on myocardial contractile function was described in the works of Atkins et al. [21] and Willerson et al. [22]. The mechanism of the positive inotropic effect of hypertonic mannitol solution constitutes a separate interesting problem, and is not clear at this time.

The results of previous series of studies, in which mannitol was infused on the traditional schedule in conventional doses, but rather rapidly, as well as the results of the present studies, warrant the statement that the rate of infusion has an appreciable influence on extent of hemodynamic changes. Infusion of 20% mannitol at the rate of 5 mℓ/min makes it possible to attain a rather marked dehydration effect on brain tissue, with minimal hemodynamic changes, as confirmed by examination of retinal hemodynamics. We should also stress the beneficial influence we demonstrated on contractile function of the myocardium, particularly since such an effect was also observed when mannitol was given rapidly. Monitoring of electrolyte composition of blood plasma failed to demonstrate any appreciable changes.

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UDC: 612.745.6:612.789

STUDY OF OPERATOR'S VERBAL INFORMATION IN THE COURSE OF COMPLICATED AND COMBINED ACTIVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 3 Jun 81) pp 25-27

[Article by N. V. Krylova and A. K. Bokovikov]

[English abstract from source] This paper presents the results of studying speech characteristics of the operator performing control and observation operations, information reception, transmission and processing, as well as decision making when exposed to a real stress (parachute jumps). The study has revealed form and content speech characteristics whose variations reflect the level of operator's adaptation to stressful activities.

[Text] The study of the role of speech in performance of purposeful activity by man is of great theoretical and practical importance.

There are, in particular, grounds to believe that when an operator verbalizes (describes his actions--operator reportage) concurrently with performance of an operation this will improve the main features of performance and, consequently, improve the effectiveness of training.

Our objective here was to study the distinctions of operator reportage and demonstrate the speech parameters characterizing the degree of an operator's adjustment to complicated and combined work in the presence of real stress.

In order to create real stress, we used parachute jumps involving stages of free-fall and opening the parachute, so that we were able to recreate, to some extent, the emotional background inherent in a number of professions (researcher [tester], pilot, cosmonaut, etc.).

Methods

We conducted this study in two stages. The parachutist-operators who participated in the study were arbitrarily divided into three groups: the first consist of novice parachutist who had made up to 20 jumps before the study; the second and third consisted of parachutists who had made 300-500 and 2000-4000 jumps, respectively.

At the first stage of the studies, the 1st group of parachutists had to report on their actions and the situation from the time the parachute opened until they touched ground. At the end of the first stage, they also performed more complicated tasks, such as jumping with 10-50-s delay in opening the parachute (free-fall) and simultaneous reporting about the situation and thier actions. The 2d and 3d groups of parachutists had to maintain operator reportage from the very start of the study, at the free-fall stage. In addition, all of the parachutists had to perform additional assignments differing in difficulty: observation and analysis of special signals displayed on the ground; various psychological tests dealing with reception and processing of information; solving problems of information retrieval on a tight time schedule [shortage of time conditions], and others.

At the second stage of the studies, the assignment for all parachutists was the same: to jump so as to converge in free-fall (converging of two parachutists) with concurrent reportage about their actions and their partner's actions while performing the assignment.

The reportage was recorded from the time they prepared to jump, aboard the helicopter, and at all stages of the jump. Miniature dictaphones were used to record the reportage. The microphone was placed in a noise-proof capsule (mask) near the operator's lips, and he had to do the following: report clearly and promptly about his actions in the process of his work; to perform other actions (control, observation, tracking and others) concurrently with the reportage.

At the first stage of the studies, the operator's reportage had to contain the following: description of the position of his body, description and evaluation of his actions, evaluation of the situation in the air and on the ground; instrument readings; description of how he felt and emotional manifestations; reports about unforeseen circumstances.

At the second stage, he had to report the following: position of his body in space; location of partner; distance between him and his partner; speed of converging with his partner; instrument readings, as well as additional description and appraisal of his and his partner's actions.

Results and Discussion

First stage of the studies: The results of analysis of the reports enabled us to create a multilevel outline reflecting the structure of perceptual and intellectual processes related to performance of a concrete form of activity. The process of learning operator reportage required making the assignments gradually more complicated. At the start of training, the operator had to report about himself and his actions. Then the operator's reports had to contain information about his surroundings. If he performed the task, a more difficult one was given to him. We submit below examples of operator reportage during free-fall.

Level 0. Silence
Level 1. Emotional manifestations: Ah! ...Oops! ... Wheeee!... Good!

Level 2. Performance of simple reportage tasks: counting time, reading instruments: ...1103, 1104 ..., 1106 ... ... 10 s, altitude 2000 m, ... 15 s ....

Level 3. Description and evaluation of body position: ... Stable fall. Hands, legs spread out....

Level 4. Description of his actions with time lag: Turned to circle.... It opened....

Level 5. Description of actions at the time they are performed: ... Am falling stably.... Turning to circle.... Making a turn....

Level 6. Description and appraisal of situation on the ground and in the air: ... There's a forest under me.... An aircraft standing at the airport....

Level 7. Planning, forecasting his actions: ...I will turn slightly to the left.... Now I will pull the ring....

The training proceeded with brief (up to 20 s) delay in opening the parachute. The reportage assignment was rather simple: counting time of free-fall, describing body position. As the subject learned reporting and jumping, the free-fall time was increased (to 50 s) and reporting assignment made more complicated. The results of analysis of the reports revealed that there are 0 to 3 of the levels, which we arbitrarily singled out, at the initial stage of training in the speech of the operator. Subsequently, as he adjusted to difficult levels of activity, the reportage became more meaningful and could include all of the levels, from 0 to 7.

Second stage of the studies: Comprehensive analysis of the reports enabled us to construct the following multilevel scheme of reflection of the situation in the speech of a parachutist-operator when performing group activity.

Level 1 (4 sublevels):
- 1.1. Silence.
- 1.2. Emotional manifestations.
- 1.3. Description of his body position and actions. At this level the operator describes and analyzes his actions after they have been performed.
- 1.4. Information about performance of simple actions (reading instruments).

Level 2 (3 sublevels):
- 2.1. Description and assessment of his actions. The actions are described while they are being performed.
- 2.2. Description and appraisal of situation in the air and on the ground.
- 2.3. Description and appraisal of joint actions; the actions are described after they have been performed.

Level 3 (3 sublevels):
- 3.1. Description and appraisal of joint actions, actions are described while they are going on.
- 3.2. Description and appraisal of situation. The operator describes a situation that is already stabilized (i.e., we receive information with some time lag).

3.3. Description and appraisal of partner's action. The descrip- of actions is given with a delay (i.e., when the action has been performed).

Level 4 (3 sublevels):

4.1. Description and assessment of situation. The situation is described without time lage.

4.2. Description and appraisal of partner's actions. Actions are described while they are being performed.

4.3. Planning and forecasting one's actions.

The levels we singled out of reflection of the situation in the speech of a parachutist-operator correspond to different stages of parachutist-operator training.

The change from one level to the next is gradual.

Analysis of the results of our study showed that there was a change from reports given about some action (situation) with a time lag to "dynamic" reports, which were made right at the time of the action. Elements of planning and forecasting appear with appearance of verbal statements.

Operator's speech can be used as a source of information about the progress of a professional activity, as well as dynamics of changes in the operator's condition.

UDC: 613.6:517.948.35]-07:612.789

USE OF VOICE COMMUNICATION TO STUDY OPERATOR ACTIVITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 3 Jun 81) pp 27-29

[Article by A. P. Bebutov, V. V. Danilovtsev and N. V. Krylova]

[English abstract from source] This paper presents the results of studying operator's activity combined with voice communications. It is shown that the quality of control functions of the operator does not decrease and in some events even increases when he runs simultaneously a reportage. An analysis of operator's reportages makes it possible to understand better the process of problem solution associated with the control over moving objects.

[Text] Our objective here was to investigate the possibility of organizing operator activity (OA) that combines control and reportage processes. A special reportage was organized, which would serve not only as the source of information about the process for solving a visually presented problem to the operator, but be instrumental in activating this process.

Methods

We examined the possibility and efficacy of using operator reportage in studies conducted on a special stand lasting many days.

The subject had to perform tasks pertaining to control of a dynamic object, which moved in the form of a cursor ["lighted marker"] over the screen of a cathode-ray tube (CLT) following different trajectories. The operator had to use a control lever to either compensate for deflection of the object from its initial position in the center of the screen (in the case of compensatory tracking) or have it superimposed with a cursor moving on the screen (pursuit mode). In the course of a 3-h session, the operator performed up to 40 tasks differing in type of control (ranging from control of displacement to control of acceleration) and modes (static, pursuit, compensation); three of these tasks were associated with reportage, and before each of them the subject performed a completely identical control task but without reportage (background problem).

Before each task, the subject studied the instructions on how to make a reportage and ran practice reportages until he had learned thoroughly all of instructions and attained stable parameters for quality of a concrete

reportage (3-5 practice sessions). The tasks with reportage were distributed evenly over the entire test period. Each operator was presented with nine variants of tasks referable to control, which had to be performed with a reportage, in order to avoid stereotype presentation of all reportages. Thus, each operator ran two reportages referable to control tasks with absolutely identical parameters over the entire test period, with the exception of three problems that were repeated three times, the first reportage of this type (according to control parameters) being referable to one of the first 3 days of the tests (initial period), the second on one of the next 3 days in the mode of continuous activity (MCA) and, finally, the last three reports (for the three control tasks singled out) were performed after the MCA.

We selected tasks differing in the following parameters as jobs pertaining to control of a dynamic object in the case of combined activity:

I. Type of control: 1) horizontal control of acceleration and vertical control of speed; 2) horizontal control of acceleration and vertical for displacement.

II. Mode of work: 1) "static"--the task consisted of outlining with a cursor a stationary square projected on the CRT screen; 2) "compensation"--dynamic compensation for "departure" of object of control from stationary target in the center of the CRT screen; 3) "pursuit"--superimposing object of control over target moving on the screen; 4) combination of modes 1 and 2, i.e., the task was to outline with a cursor a square moving over the CRT screen; 5) combination of modes 1 and 3, i.e., outlining the square when a "perturbation" was imposed on the cursor.

Thus, the nine variants of control tasks performed simultaneously with reportage constituted different combinations of the above types and modes of control.

In the reportage (according to instructions for running reportages), the operator had to reflect the following elements (tags) of problem solving: type of target (shape) and characteristics of its movement (for example, the target in the form of a black square moves regularly over the plane of the screen); type of cursor and nature of "perturbation" on it (for example, in the form of a white cross; the "perturbations" are at random and have an identical "effect" on the cursor over both control axes in the plane of the screen); work mode ("static," "compensation" or "pursuit")' brief analysis of the situation (mutual location of target and cursor, relative movement thereof, change in contrast and shape of figures, etc.); degree of inertia of the transfer element of controlling cursor on each axis (for example, "velocity" is controlled on the horizontal axis and "displacement" on the vertical one); analysis of his own actions to control cursor (for example, if cursor goes to the left, the operator turns the knob to the right for 1-2 s, then returns it to the initial position; since he is controlling acceleration, he must take into consideration the "delay" in cursor reaction. Thus, the cursor gradually returns to the target. As it approaches the target the knob [lever] must be turned sharply to the left for 0.5 s in order to eliminate the gained inertia of movement, etc.); determination of difficulty of task (on a 3-point scale: simple, average difficulty, difficult); assessment of results (on a 5-point scale).

We tested nine operators in all (27-30 years old), whose professional activity was similar to what we used. Each operator worked with the unit [stand] for a total of 21 h over a 7-day period (3 h/day), and the MCA was used for 3 days.

There are two expressions for assessment of quality of operator performance, absolute and relative.

The absolute evaluation consists of total time for finding object of control on target in the course of standard problem solving time for each task (120 s). This rating is made on a 100-point scale (0--cursor was never on target throughout problem solving time; 100--the opposite situation). The relative evaluation (percentage) is characterized by the relationship of absolute performance scores (completely identical control parameters) with and without reportage (i.e., "background problem"). Standard deviations (given in parentheses) are listed for each group of subjects. Also given is the rating for quality of operator reportage (QOR, on a 10-point scale) averaged for the group.

An arbitrary scale was developed to score QOR with regard to informativeness. The highest score (10) was given to a reportage in which all 10 tags were used in accordance with the instructions; 0 corresponded to refusing to give the reportage. If fewer than two-thirds of all tags were used in the report, the score was up to 6 and with one-third the tags, the score was up to 3. We considered each time the meaningful aspect of the report: thoroughness of performing given task (i.e., distinctness of reflection in speech of the presented visual situation and of actions), volume of verbal material, number and duration of pauses.

Results and Discussion

As can be seen in Table 1, addition of specially organized reportage not only failed to reduce the quality of performance of the main control task, on the average for all subjects, but in some cases reliably increased this parameter, as compared to the background. Thus, averaging of parameters for all types of tasks with reportage (see Table 1) gives us a relative score of 106, with confidence limits of 101-111, which enables us to state that, on the average, the reportage had no adverse influence on concurrent performance of control task. We failed to demonstrate a reliable correlation between quality of operator work and operator reportage. Table 2 lists absolute scores for quality of operator performance without reportage and with concurrent reportage. The first column lists the sequential numbers of background tasks in order of their difficulty, and the second corresponds to difficulty of performance of tasks with reportage. Analysis of the data in Table 2 warrants the following conclusions. The quality of the reportage changed in accordance with difficulty of several groups of tasks. Thus, tasks 2a and 3a "switched" numbers for difficulty; consequently, it is easier to verbalize compensatory tracking problems than "pursuit" ones. The content of reportages about these tasks also served as an indirect indication of the same thing: less information material is used to describe compensatory tracking than pursuit. In the "pursuit" task, the subjects analyze the form of the given trajectory of movement,

whereas in describing compensatory tracking they limit themselves to reporting the chaotic nature of perturbation. Perhaps these distinctions of description of the tasks in question are the cause of "redistribution" of difficulty of performing them with concurrent reporting.

Table 1.
Absolute and relative scores for quality of OA in controlling a dynamic object and score for quality of operator reportage (OR) for each work mode (M±σ)

Background problem No	Type of control	OA quality absolute	OA quality relative	OR quality
1	1a	75±1,8	96±3,2	7,0
2	2a	74±2,3	111±3,7	7,3
3	3a	72±0,8	99±4,4	7,8
4	3в	71±1,3	114±6,3	6,8
5	4a	69±1,9	106±9,8	7,3
6	5a	67±1,4	112±11,2	7,8
7	2в	66±1,3	109±9,4	6,5
8	4в	61±3,7	110±15,1	6,5
9	5в	51±6,2	98±7,4	6,8
Mean		67±3,0	106±5,1	7,1

Table 2.
Influence of reportage on performance of tracking task

Task No without reportage	Task No with reportage	Type of control	Quality of task without reportage	Quality of task with reportage
1	1	1a	78±2,6	75±2,1
2	2	2a	75±1,8	72±1,1
3	3	3a	73±1,1	74±1,3
4	4	2в	72±1,2	71±2,1
5	5	3в	70±2,3	66±4,0
6	6	4a	62±4,2	69±2,3
7	7	5a	60±2,4	67±1,4
8	8	4в	56±3,2	61±2,7
9	9	5в	53±2,7	51±3,4

Tasks 4a and 5a also "rose one step," as compared to the "background," whereas problem 3b "dropped two steps," in relation to its background position. This shows that performance of the task of compensatory tracking with maximum difference in differentiation of control axes (movement on one axis and acceleration on the other) is more difficult than the performance of combined tasks (4a and 5a) where there is less difference in degree of differentiation of control axes (speed and acceleration).

Addition of special reportage has a beneficial effect on performance of the most difficult control tasks. Thus, the difference between scores becomes positive for tasks 4a, 4b and 5a (see Table 2), which is indicative of better performance of these tasks than in the background (with the exception of task 5b, which is on the "borderline" of difficulty of performance). Evidently, the attempt to "verbalize" the structure of activity he is performing enables the operator to analyze more objectively the strategies for solution and consequently to better succeed in finding the optimum one.

It is important to note that the content of the reportages is a source of additional information for analysis of individual psychological distinctions of operators.

Inclusion of a special reportage in the mode of combined activity while performing tasks for manual or semiautomatic control of a dynamic object (tracking) may make it possible to investigate operator activity more thoroughly

and to exercise a beneficial effect on its quality, particularly when solving complex operator problems. These reportages must be informative enough for expanded investigation of this type of activity.

Our study enabled us to formulate the following principles for organizing such reportages: there must be a semantic relationship between the reportage and work performed; instructions for running reportages following the same system; holding preliminary practice of reporting concurrently with tracking (until stable parameters are attained).

UDC: 613.693:612.766.1

DYNAMICS OF FUNCTIONAL STATE OF HEAVY TRANSPORT HELICOPTER PILOTS IN THE COURSE OF FLIGHT SHIFT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 16 Mar 81) pp 30-32

[Article by Yu. N. Kamenskiy]

[English abstract from source] Before and after flights about 300 crewmembers of heavy transport helicopters were examined, using psychophysiological and integral methods that yield professionally important information. During a flight shift the health state of helicopter pilots varies via three stages: habituation, initial decline and distinct lassitude, with the latter developing after 5 h flight load. In order to increase human reliability in the pilot-helicopter system, it is advisable to allow 4 h flight time during a flight shift onboard helicopters of the above type. In this case the pilot exposure to vibration effects will also be limited. The paper describes a maximally permissible spectrum of vibration velocity for a 4 h exposure.

[Text] Problems of determining the functional state of pilots in order to forecast their professional reliability are directly related to the problem of flight safety and regulation of flight load. As they apply to helicopter aviation, the solutions to these problems have their own distinctions, which are related to the specifics of flying helicopters and working conditions of flight personnel. The data pertaining to degree and rate of changes in functional state of helicopter pilots in the course of the flight shift are contradictory and vague [1, 2].

Our objective here was to examine the dynamics of functional state of pilots in the course of a flight shift in order to forecast their reliability in the pilot-helicopter system, to optimize schedules and improve working conditions.

Methods

We examined about 300 crew members of heavy transport helicopters, who made routine flights. The study was made 60-90 min before the start of the flight shift and 40-60 min after its end.

Our examination included recording of critical flicker fusion frequency (CFFF), accuracy of movement coordination (AMC), accuracy of reproducing a muscular exertion (ARM), reaction to moving object (RMO), pulse rate (PR) and arterial pressure (AP). The results of RMO were assessed on the basis of the ratio of number of premature reactions (RMO_p) to number of delayed reactions (RMO_d). We arbitrarily designated this ratio as the parameter of nervous processes (PNP). The aggregate of physiological functions and psychological traits evaluated by the above-mentioned methods characterized the functional state (FS) [3].

All of the pilots were divided into seven groups according to hours logged per shift (1 to 7 h). We took data referable to only 20 people per group for analysis in order to standardize the groups according to age, jobs and number. In all, the sample consisted of 140 people.

The results were submitted to statistical processing on the condition of 95% reliability of differences between means.

Results and Discussion

The initial psychophysiological parameters of different groups were essentially the same, and this served as grounds to calculate overall mean base values.

After logging 1-2 h, CFFF, AMC, ARM and hemodynamic parameters showed mainly an increase. After logging 3-4 h, there was an increase in number of negative changes, which began to prevail after logging 5 h and persisted at this level after 6 and 7 h.

Dynamics of changes in psychophysiological and autonomic parameters of pilots during flight shift (M±m)

Parameter	Background	Logged hours						
		1	2	3	4	5	6	7
CFFF, Hz	34,8± 0,6	36,0±0,4	35,7±0,4	33,3±0,6	34,8±0,4	31,9±0,4*	32,2±0,5*	32,0±0,4*
AMC, arbitr.units	3,8± 0,39	4,1±0,47	4,3±0,44	2,9±0,26	2,7±0,22*	2,1±0,18*	1,9±0,13*	1,7±0,13*
ARM, " "	3,7± 0,42	4,0±0,34	4,6±0,34	3,5±0,40	3,4±0,40	1,9±0,15*	1,9±0,10*	1,8±0,10*
PNP, " "	1,11± 0,23	1,41+0,09	1,29±0,07	0,68±0,06	0,58±0,04*	0,36±0,02*	0,34±0,04*	0,28±0,02*
PR, per min	70± 1,0	74±1,2	74+1,4	75±1,3	80±1,6*	79±1,5*	78±1,4*	78±1,4*
AP_{max}, mm Hg	117± 1,5	119+1,7	119±1,6	125±1,8*	128±2,1*	123±2,0*	123±2,2*	124±2,1*
AP_{min}, mm Hg	77±1,0	78±1,1	76±0,9	84±1,4*	83±1,5*	80±1,3*	78±1,6*	74±1,5*

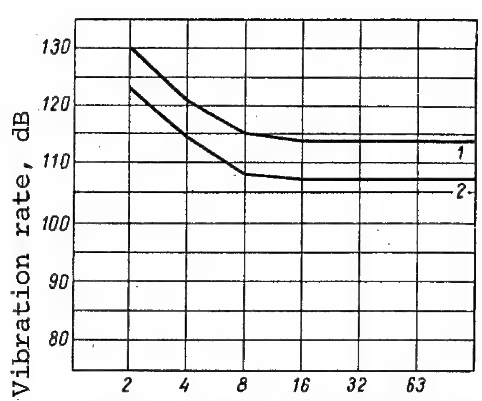
*$P<0,05$.

The quantitative expressions of the parameters are listed in the Table. At the start of the flight shift, there was reliable increase in CFFF by 3.4-2.6% and in PNP by 27.0-61.3%; there were insignificant changes in PR and AP. After logging 3-4 h, all of the psychophysiological parameters declined, but only AMC and PNP diminished reliably, as compared to the base level (by 24.2-28.5% and 38.7-47.7%, respectively). At this time, hemodynamic parameters were reliably higher than base values.

After logging 5 h, there was drastic decline of all psychophysiological parameters: CFFF by 8.3%, AMC by 44.7%, ARM by 48.6% and PNP by 67.6%. Hemodynamic parameters had a tendency toward some relative decline. After logging 6 and 7 h, all of the parameters became stabilized at a low level, with the exception of PR and AP, which retained a tendency to decline.

On the whole, the dynamics of FS of pilots were characterized by improvement after logging 1-2 h, relative worsening after 3-4 h, drastic worsening after 5 h and stabilization of the last level after logging 6-7 h. The improvement of FS of pilots at the start of the shift reflects the so-called phase of "warming-up" to the work. Relative worsening of FS after logging 3-4 h could be qualified as a sign of incipient fatigue. These FS changes coincided with appearance of subjective signs of fatigue and preceded progression thereof. Thus, a sense of fatigue appeared in 15.3% of the pilots after logging 4 h, 42.8% after 5 h, 86.7 and 85.7% after logging 6 and 7 h, respectively. There was an analogous increase in number of cases of negative attitude toward flights: 35.7, 66.7 and 78.6% after logging 5, 6 and 7 h, respectively.

The hemodynamic changes in the course of the flight shift were in the nature of a compensatory and adaptive reaction aimed at maintaining the current FS, in particular of the sensorimotor functional system. The relative decline of hemodynamics at the end of the flight shift was probably due to development of fatigue. Depression of the adrenosympathetic system as a result of prolonged exposure to vibration could be one of the mechanisms of this phenomenon [4].



Recommended maximum spectrum of vibration rate in crew cabins of helicopters for 4-h exposure
1) recommended spectrum
2) permissible spectrum according to GOST 12.1.012-78 for general transport vibration

The question of standard flying hours per shift for helicopter crews is directly related to pilot fatigue. This matter has not been worked on sufficiently, and heretofore the necessary differentiation had not been made according to working conditions in different types of helicopters [1]. Yet such a flight factor as vibration plays a very definite part in development of pilot fatigue, and this could be the cause of accidents [5]. Conditions for flight accidents at the end of the shift have been often present when flying helicopters for 8 h per day. Reduction of flying time to 4 h/day led to complete disappearance of such conditions [6]. On the other hand, flying in helicopters for 18 h/day is qualified as the top limit of a normal flight load under simple meteorological conditions [7]. However, such a load is acceptable only for test pilots with a high level of flight motivation who make flights sporadically. Routine, daily flights do not prompt such motivation, and already for this reason elicit rapid fatigue of pilots.

Apparently, a level of pilot degree, at which a wide range of flight safety is assured due to the "personal factor," must be the criterion in setting standards for logged hours per flight shift. For this reason, there is validity to the view that physiologically substantiated standards for flying hours must assure the absence of marked signs of fatigue at the end of the work day. Thus, 4 h per day should be considered the standard for flying heavy transport helicopters, and this is consistent with data of other researchers who set flying hour standards with consideration of intensity of the vibration factor [5, 8].

Measurements we took together with Yu. G. Matveyev revealed that the level of vibration in the octave range of 16 Hz constitutes an average of 114 dB in the crew's cabin of a heavy transport helicopter. Proceeding from the data on time of development of pilot fatigue, it can be assumed that maximum time of exposure to vibration of 114 dB should be limited to 4 h per flight shift.

If the 16 Hz octave is considered as the base for this type of helicopter, one can plot the permissible spectrum for 4-h exposure on the basis of the requirements in GOST 12.1.012-78 (see Figure). The proposed limitation of pilot exposure to vibration provides conditions for optimizing work schedules, makes it possible to preserve high work capacity of crews and improves flight safety.

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UDC: 629.78:612.766.1

CONTROLOGRAPHY USED FOR INTEGRAL ASSESSMENT OF MENTAL WORK CAPACITY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 15 Apr 81) pp 32-35

[Article by K. K. Ioseliani, A. L. Narinskaya and Sh. R. Khisambeyev]

[English abstract from source] Man's mental performance was evaluated with the aid of a controlograph. As a result, three groups with a high, medium and low level of mental performance were detected. It was found that the method of controlography can be used to predict man's capacity to perform complex operational functions. An integrated evaluation of mental performance by means of the controlographic technique was in good agreement with the results obtained by the traditional methods.

[Text] Integral assessment and forecasting of the operator-cosmonaut's mental work capacity constitute pressing tasks at the present stage of development of cosmonautics. One must take into consideration the fact that the most typical work of a cosmonaut-operator at the most important phases of flight is mental work of the sensorimotor type, which consists of receiving and processing a large amount of extremely complex and diverse information, and elaboration of specific motor reactions on the basis of the existing conceptual model [1]. Under such conditions, mental work capacity is based on individual psychophysiological personality traits, in addition to special knowledge and skills.

In our country, the integrated [combined] and systems approach to this problem is the main direction of research on mental work capacity [2]. Soviet psychology is governed by the principle, according to which performance is viewed as the source of diverse products of the mind, a thesis that provides for uniting cognition and practice, regarding labor as the highest form of activity to be of paramount importance [3]. Thus, the theoretical sets of scientific psychology direct psychologists toward an effective and systems approach to the study of mental work capacity. From this point of view, the inadequacy of traditional analytical methods, which amount to isolated investigation of separate mental functions, is particularly perceptible. When such methods are used, the subject's personality is often replaced with a set of some mental properties or other. Evidently, such methods and, first of all, tests that make use of forms, can assess one or, at best, several elements of work capacity, but not performance as a whole. There is also a

popular synthetic approach, in which so-called work tests and simulators are used as a method of psychological experimentation, in which psychologists resort to imitating the concrete work of a narrow specialty. These methods, which require prolonged training, well-developed specialized skills, which simulate only some forms of activity, are also incapable of characterizing the mental work capacity of an operator as a whole. Thus, the need for methods of integral evaluation of the main mental functions and mental work capacity has not yet been met.

In our quest for an adequate and integrated method of assessing and forecasting mental work capacity, we were governed by an integral method of psychological investigation that combines both analytical and synthetic procedures. Evidently, to implement such a method, we have to use a universal model, new for all subjects, of complex operator work, which would require mobilization of psychophysiological reserves of subjects.

Complex differentiated activity of the sensorimotor type, performed by means of an electronic mechanical instrument, the controlograph (designed by Ya. I. Tsurkovskiy) served as such a model for us; a special program was used that related to tasks of space psychophysiology. The program provided for combined evaluation of the main mental functions: attention, operative memory, graphic imaged thinking, object-related, spatial and color gnosis in the presence of informational interference of both the homogeneous and heterogeneous type, as well as limit and shortage of time.

Methods

The method we used consisted of projecting on a screen panel some slides showing combinations of geometric figures. Each frame was arbitrarily divided into two rows (top and bottom) and five vertical sections. The subject had to examine the projected frames carefully for short periods of time and detect absence or incorrect arrangement of elements of geometric figures in accordance with the specified conceptual model. In addition, by pressing on the appropriate keys and pedals of a register, he had to note the location of the detected irregularities (indicate the row and section) or confirm that the exhibited frame was completely correct. All of the subject's answers were recorded on chart paper [tape] with a multichannel automatic recorder. In the intervals between presentation of the frames, red and green lights were turned on around the screen. Incorrect order of turning them on or, on the contrary, complete conformity to the sample were recorded by pressing on the appropriate keys.

In processing the obtained data, we took into consideration the subject's reaction time in response to complex optical and acoustic stimuli, number of correct and wrong answers, nature of mistakes and overall performance time. We calculated the coefficient of achievement in the form of a unitary percentage score on the basis of these parameters, using special formulas [4].

We used controlography to test the mental work capacity of 18 essentially healthy subjects ranging in age from 20 to 42 years.

Results and Discussion

The data we obtained enabled us to divide all of the subjects into three groups.

The first group consisted of subjects characterized by high initial level of work capacity, low number of mistakes and skips over the entire period of the study (33% of all subjects). They were notable for high emotional stability, ability to mobilize themselves in stressogenic situations. They performed their tasks with concentration and effort, but without strain and constraint. Involvement in the test did not elicit any difficulties; they readily developed new stereotypes of complex sensorimotor skills, which persisted for a long time. Interference and forced acceleration of work pace did not diminish appreciably the quality of performance; there were insignificant manifestations of fatigue at the end of the task. Mean unitary percentile score for the group was 93.4%.

The second group included subjects whose achievements were not high at the start of the study, but who subsequently improved. At first, they made many mistakes and skipped many times. They presented a significant reaction time to complicated optical and acoustic stimuli, uneven work pace and controlled anxiety. With appearance of informational interference time limit and shortage, they did not have time to react promptly to exhibited cues. In the structure of actions of such subjects there was prevalence of delays, which was indicative of slowing of mental processes. However, as they became more trained, this group of subjects showed rapid improvement in quality of performance, even when a faster pace was forced upon them, demonstrating good learning (50% of the subjects). The mean unitary score for this group was 85.29%.

The third group consisted of individuals with low initial level of mental work capacity and poor learning ability (17% of the subjects), They were constrained and confused. They tried very hard to perform their tasks; however, excessive bustling and irritability were manifested when there were difficulties. There was difficult development of skills. In view of the large number of mistakes, they often had to repeat the test from the very beginning after being given additional explanations and instructions. As a rule, this group of subjects named out loud all of the operations they performed, which could mean that there was inadequate interiorization of skills. In the presence of informational interference and shortage of time, they became confused, the quality of their performance diminished markedly and there were long delays in giving some answers. They made many mistakes when the work algorithm was changed, which was apparently related to poorer capacity to switch attention and small volume of short-term memory. Interestingly, the required cues given by the experimenter sometimes had the effect of interference, rather than a corrective influence. There was insignificant improvement in performance when the tests were repeated. Their mean unitary scorewas 68.3%. These findings indicate that controlography makes it possible to determine not only the level of mental work capacity, but possibility of improving it in the course of learning and training. This opens the way for predicting mental work capacity at different stages of performance of operator work of the sensorimotor type. Controlography, which has high prognostic value and

informativeness, could improve significantly the effectiveness of the system of screening and expert evaluation of cosmonauts. It should also be borne in mind that contrographic testing does not require more than 1 h, and the subject does not have to be trained for a long time to obtain a "plateau."

The results of the contrographic study were compared to scores on a 9-point scale obtained by means of the methods of "continuous counting at a specified pace," "retrieving numbers with switching over" and "cancellation test" used in the practice of space psychophysiology in order to validate contrography for use in space psychophysiology. The integral score of mental work capacity by the former methods constituted 8.5 for the first group, 7.7 for the second and 5.2 for the third. These scores are consisted with the results of the contrographic study (93.4, 85.29 and 68.3%, respectively), which enabled us to rank them on the 9-point scale. Evaluation of the results of the contrographic study on a 9-point scale makes it possible to give a quantitative assessment of the level of mental work capacity in units that are comparable to those used with other methods.

The obtained data warrant the belief that introduction of contrography to the practice of space psychophysiology will make it possible to provide an integral evaluation of mental work capacity in each concrete case, at the stages of cosmonaut screening and training.

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UDC: 629.78:612.172-06:612.766.2.014.421.7

SEISMOCARDIOGRAPHIC EVALUATION OF CONTRACTILE FUNCTION OF THE MYOCARDIUM OF HYPOKINETIC RATS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 3 Jun 81) pp 35-38

[Article by V. I. Kuznetsov]

[English abstract from source] The possibility of seismocardiographic recording in rats has been explored and SCG time and amplitude parameters have been determined. The measurements have been performed in normal rats and hypokinetic rats with an altered cardiac contractility. The SCG data obtained in hypokinetic rats have been compared with the results derived from contractility studies by heart catheterization and subsequent calculation of contraction strength and velocity. It has been shown that the data compared are similar on hypokinetic days 1 and 5. This suggests that the seismocardiographic method of studying heart contractility function of rats is adequate for integral evaluations of the strength and velocity of cardiac contractions in chronic experiments. On hypokinetic days 15 and 30 the data obtained by catheterization and seismocardiographically are at variance. This may be attributed to muscle mass losses and variations in the rigidity of "internal" bonding.

[Text] Seismocardiography is one of the rather new and important methods of monitoring the condition and functional capacity of the myocardium. It was first used in space medicine [1, 2]. Then it was used with success in sports medicine [3]. At the present time, seismocardiography has been tested in clinical practice on patients with various types of cardiovascular pathology [4, 5]. The advantages of this method have been reported, and it permits making an indirect judgment about myocardial contractility; seismocardiography has been recommended for polycardiographic tracings instead of phonocardiography when conducting functional tests.

Experimenters working with animals often need a method of assessing mechanical activity of the myocardium in chronic experiments. Polycardiograms of rats were recorded by some authors [6, 7] for this purpose, followed by phase analysis of the systole. However, the results obtained by this method were found to be uninformative.

We have undertaken here an attempt to record seismocardiograms (SCG) in experiments on rats to test contractile function of the myocardium. We did not encounter data in the literature concerning SCG on small laboratory animals. This study was conducted in two stages; at the first stage, we refined the technique for recording SCG and obtained data on time and amplitude parameters of SCG in healthy rats; at the second stage we determined the informativeness of this method of examining myocardial contractile function. For this purpose we used the model of hypokinetic rats. Contractile function of the myocardium under hypokinetic conditions had been studied by the method of cardiac catheterization with subsequent calculation of parameters of force and rate of cardiac contraction [8-10].

Methods

Experiments were performed on 120 female mongrel white rats weighing 180-250 g, in the springtime. Control data (1st stage) were obtained on 40 rats. The second stage involved the use of 30 rats submitted to immobilization by placing animals in individual plexiglas cages, where movement was very restricted. We used a piezoelectric seismocardiographic sensor.* The sensor was placed on the left side of the rat's chest, with the animal in horizontal position under urethane anesthesia (160 mg/100 g body weight, intraperitoneally), and it was isolated from the hard surface of the table with a foam rubber liner. We recorded SCG with the use of a filter, synchronously with the EKG in the 3 standard leads using an ELKAR-4 unit 24 h after immobilization, then on the 5th, 15th and 30th days of the experiment. Paper feeding rate was 100 mm/s. The obtained data were compared to the results of testing myocardial contractility by the direct method. Conventional methods were used to measure intraventricular pressure and subsequent calculation of parameters of force and rate of contraction [9]. The data were submitted to statistical processing. Reliability of differences between mean values was determined with the criterion of Wilcoxson-Mann-Whitney [11]. The differences were considered reliable with $P<0.05$.

Results and Discussion

At the first stage, in 36 out of the 40 tested animals we recorded SCG that distinctly demonstrated two oscillatory cycles, A_1 and A_2 (see Figure). We consider it possible to calculate the following SCG parameters on the basis of analysis of the obtained curves: A_1--amplitude of first (systolic) oscillatory cycle; A_2--amplitude of second (diastolic) oscillatory cycle; t_{A_1}--duration of oscillatory cycle A_1; t_{A_2}--duration of oscillatory cycle A_2; $t_{A_1-A_2}$--duration of mechanical systole (time from start of first to start of second oscillatory cycle).

In addition to these main parameters, whose values are listed in Table 1, we determined the electromechanical delay--time from start of Q wave or, in the event there was none, R wave on the EKG to start of cycle A_1 on the SCG,

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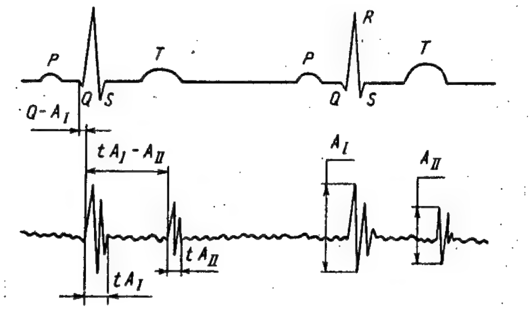
*We express our gratitude to Prof R. M. Bayevskiy for his methodological and consultant assistance in this work.

and ratio of amplitude of first oscillatory cycle to amplitude of the second. Mean electromechanical delay constituted 0.023±0.006 s and mean amplitude ratio was 2.0±0.54.



CSG time and amplitude parameters

At the second stage of the experiment, we examined the SCG of hypokinetic rats. There were phasic changes in amplitude of cycle A_1 during the 30 days of immobilization: 55% increase after 24 h, 35% decrease on the 5th day, 67 and 110% increase on the 15th and 30th days, respectively (see Table 1). There was 15% decrease in duration of oscillatory cycle A_1 after 24 h of immobilization, whereas it did not differ reliably from the control on the 5th, 15th and 30th days.

Table 1. SCG parameters of hypokinetic rats (M±m)

Parameter	Control ($n=36$)	Duration of immobilization, days			
		1 ($n=28$)	5 ($n=17$)	15 ($n=15$)	30 ($n=15$)
A_1, MM	12,5±2,4	19,4±3,6*	8,1±1,0*	20,9±1,2**	26,2±1,7***
A_2, MM	6,[illegible]±1,3	6,[illegible]±1,4	3,5±0,5*	5,5±0,4	8,1±1,4*
t_{A1}, s	0,034±0,002	0,0[illegible]9±0,001*	0,033±0,005*	0,032±0,006	0,034±0,002
t_{A2}, s	0,029±0,002	0,022±0,003*	0,020±0,003*	0,023±0,004	0,025±0,005
t_{A1-A2}, s	0,075±0,003	0,045±0,002***	0,089±0,003*	0,075±0,008	0,068±0,006
Heart rate, per min	492±11	5[illegible]5±10*	474±16	488±15	503±13

Here and in Table 2:
*P<0.05 **P<0.01 ***P<0.001
Number of animals is given in parentheses.

The amplitude of cycle A_2 after 24 h of hypokinesia did not change; it decreased by 44% on the 5th day, reverted to the control level by the 15th day and exceeded the control by 31% on the 30th day. The duration of cycle A_2 decreased after 24 h and on 5th day of hypokinesia--by 24 and 31%, respectively. It did not differ reliably from the control on the 15th and 30th days.

Parameter $t_{A_1-A_2}$ decreased by 40% after 24 h of immobilization, increased by 19% on the 5th day; duration of mechanical systole was normalized on the 15th day and held at this level to the 30th day.

Thus, seismocardiographic examination of myocardial contractile function revealed an increase in amplitude of the systolic cycle and reduction of time parameters of SCG after 24 h of immobilization, which was indicative of mobilization of myocardial contractile function under hypokinetic conditions. According to data in the literature and our findings [9, 12, 13], changes

occurring at the first stage of experimental hypokinesia, which was simulated by placing rats in individual cages, were due primarily to immobilization stress. A maximum stress reaction was observed after 24 h of immobilization (anxiety stage, according to H. Selye). At this time, there was significant activation of the adrenosympathetic system, which leads to intensification of mechanical activity of the heart [12]. By the 5th day, some rats presented exhaustion of compensatory reactions and they expired (22% death). At this stage, the surviving animals presented depression of cardiac contractile function. Subsequently, they gradually went into the next stage of experimental hypokinesia, the deconditioning stage.

Table 2. Changes in parameters of force and rate of myocardial contraction in hypokinetic rats (M±m)

Parameter	Control	Duration of hypokinesia, days			
		1 ($n=8$)	5 ($n=7$)	15 ($n=7$)	30 ($n=7$)
Intraventricular pressure, kPa	11,8±0,7	15,1±0,5*	8,9±0,6*	12,6±1,4	12,5±1,6
IFS, kPa/100 mg dry wt.	11,6±0,9	14,7±0,7*	8,7±0,6*	11,7±0,9	13,3±1,6
Contraction rate, kPa/s	442±28	635±33*	231±24***	304±22**	514±27

Key: IFS) intensity of function of structures, determined from the ratio of intraventricular pressure to unit of myocardial mass

A comparison of parameters of myocardial contractility in the presence of immobilization stress, obtained by direct and SCG methods, revealed that they matched after 24 h and 5 days of hypokinesia. Thus, the parameters of force and rate of myocardial contraction increased by 28-44% after 24 h of immobilization (Table 2) and in the tests with recording of SCG the parameter of amplitude of complex A_1 increased by 55%, duration of cycle A_1 and mechanical systole decreased by 15 and 40%, respectively. On the 5th day, the force and rate parameters of cardiac contraction decreased by 25-48%, amplitude of A_1 and A_2 also decreased by 35 and 44%, respectively, and mechanical systole increased by 19%. The similarity of these results indicates that the changes in the SCG reflect objectively the contractile function of the myocardium.

As for data obtained on the 15th and 30th day of hypokinesia, there was a discrepancy between the findings obtained by direct and SCG methods. The direct method revealed normalization of force and rate of contraction, whereas the amplitude parameters on the SCG were elevated. In analyzing this discrepancy, it must be borne in mind that prolonged hypokinesia elicits significant progressive weight loss starting on the 5th day. By the 15th-30th days, weight loss constituted 42-44%, as compared to the base value. This was related primarily to atrophy of skeletal muscles [14]. As we know, oscillations of the chest wall are recorded on the SCG. The process of transmission of movements of the heart and thoracic vessels is very complicated, since the cardiovascular system and surrounding organs and tissues constitute a single

entity, being united by means of "internal" bonds. We mean by this the links between the cardiovascular system and surface of the chest to which a part of the mechanical energy of cardiac contractions is transmitted. These links are created by tissues between the cardiovascular system and anterior surface of the thorax. Since tissues have resilient properties, the mechanical oscillations may change in amplitude and duration as they are transmitted through tissues. Atrophy of chest wall muscles under hypokinetic conditions alters the rigidity of internal connections in the direction of increase, and as a result it causes a loss of energy of cardiac contraction and increase in amplitude of oscillations picked up by the sensor. This could explain the difference between data obtained by direct and indirect methods.

Thus, seismocardiography reflects objectively myocardial contractile function, and it can be used in chronic experiments on small laboratory animals when there is insignificant change in rigidity of internal bonds.

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UDC: 629.78:612.115-06:612.223.1:546.171.1/.4

MORPHOLOGY AND COAGULANT FUNCTION OF HUMAN BLOOD SYSTEM DURING LONG EXPOSURE TO LOW AMMONIA CONCENTRATIONS IN A SEALED ENVIRONMENT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 30 Jun 81) pp 39-41

[Article by M. P. Kalandarova and L. S. Pochukayeva]

[English abstract from source] A group of test subjects was kept in a chamber in which the ammonia concentrations 5.1±0.05 mg/m^3 and 2.1±0.1 mg/m^3 were maintained for 17 and 31 days, respectively; on days 22 and 38 the ammonia concentration was increased to 9.3±0.1 mg/m^3. During this exposure the morphological composition (red blood cells, hemoglobin, reticulocytes, platelets, white blood cells and their various types), as well as the coagulative-anticoagulative system (factor IV of platelets, index of blood clot retraction, recalcification time, thrombin time, ethanol and protamine sulphate paracoagulation tests, fibrinogen degradation products, fibrinolytic activity, fibrinogen and prothrombin content) were investigated. The parameters characterizing hemopoiesis and status of the coagulative-anticoagulative system did not show any significant changes. However, a slight decrease in the counts of leukocytes, neutrophils, eosinophils is of concern, because in space flight resistance to different infections declines.

[Text] Toxicological evaluation of deleterious chemical trace impurities, including ammonia, which accumulates in a sealed environment as a result of vital functions of man and operation of equipment, is one of the important aspects of biomedical support of long-term spaceflights [1]. It is of practical and theoretical interest to study hemopoiesis and functional state of the blood coagulation and anticoagulation systems during long-term exposure to low concentrations of ammonia. There are isolated indications in the literature [2] concerning impairment of blood coagulability in the case of acute ammonia poisoning. Equivocal results were obtained from studies of quantitative blood changes under the influence of low concentrations of ammonia [3-5].

Methods

We conducted studies in a sealed [pressure?] chamber 24 m^3 in size, in which we maintained a constant concentration of ammonia of 5.1±0.1 mg/m^3 around the

clock for 17 days (first study) and 2.1±0.1 mg/m^3 for 31 days, with brief (for 1 day) elevation to 9.3±0.1 mg/m^3 on the 22d and 38th days (second study).

Results and Discussion

The results of this study revealed that the erythrocyte count, hemoglobin and reticulocyte count in the subjects' blood was in the normal range throughout the observation period while in a sealed chamber with 5.0±0.1 mg/m^3 ammonia content in the atmosphere (first study).

The dynamics of leukocyte count revealed a tendency toward decline to the bottom of the normal range (4000±600-4700±650/mm^3 blood, versus 7500±1400/m^3 in the background period). The leukocyte formula revealed a decrease to 2300±260 neutrophils, 1200±270 lymphocytes and 74±32 eosinophils/mm^3 blood, as compared to the background period (4800±320, 2600±220 and 200±90, respectively). Thrombocyte count exceeded the base value by 10-12% starting on the 15th day of the study. The index of blood clot retraction, factor IV of thrombocytes (tests characterizing functional properties of thrombocytes) did not differ from normal. Recalcification time, which reflects the state of the general blood coagulation system, did not change throughout the period of the study. Thrombin time, paracoagulation tests (ethanol and protamine sulfate), as well as amount of products of fibrinogen degradation, corresponded to values in the background period. We also failed to demonstrate appreciable changes in the blood anti-coagulation system. In particular, fibrinolytic activity did not differ from base values at all tested times. Fibrinogen content of blood was somewhat increased during the stay in the sealed chamber (480-600 mg% versus the normal 200-400 mg%). Prothrombin content corresponded to the top of the normal range or was somewhat elevated (105-108% versus the normal 80-100%).

In the second study, where we briefly raised the ammonia concentration to 9.3 mg/m^3 from the background constant concentration of 2.1±0.1 mg/m^3 in the atmosphere, erythrocytes, hemoglobin and reticulocytes were in the range of base values over the entire period of the study. Leukocyte count was in the normal range, the neutrophil content being at the bottom thereof (2100±200/mm^3 blood). We observed monocytosis at some stages. Thus, 1 day after the first increase in ammonia concentration the monocyte content increased to 610±28/mm^3 blood (versus 430±220/mm^3 in the background period). Leukocyte count was normal. Thrombocyte level showed virtually no difference from base values over the entire period of the study. The index of blood clot retraction was normal throughout the observation period. Recalcification time fluctuated within the normal range. There was slight increase in products of fibrinogen degradation on the 1st day after the second increase in atmospheric ammonia content. At other tested times, the concentration thereof was in the normal range. The paracoagulation tests (ethanol and protamine sulfate) were negative throughout the observation period.

No appreciable changes were demonstrable either in the blood anticoagulation system. Fibrinolytic activity was normal. Fibrinogen content was somewhat above normal in the background and recovery periods (450-460 mg% versus the norm of 200-400 mg%). Fibrinogen content fluctuated over the normal range during the period spent in the sealed chamber. There was no change in prothrombin content.

Thus, we failed demonstrate appreciable changes in parameters characterizing hemopoiesis, blood coagulation and anticoagulation systems while subjects spent a long time in a sealed environment with ammonia concentrations of 5.0±0.1 and 2.1±0.1 mg/m^3 in the atmosphere, and brief increase thereof to 9.3 mg/m^3. However, there was some decrease in leukocyte, neutrophil and eosinophil count with 5 mg/m^3 concentration of ammonia, and a tendency toward neutropenia with brief increase in atmospheric ammonia level to 9.3 mg/m^3, against the background of a concentration of 2.1 mg/m^3, which was indicative of diminished granulocytopoiesis.

The monocyte reaction demonstrated in subjects in the second study reflected their reactivity. Blood monocytes and tissue macrophages are presently viewed as the most important cellular mechanisms of nonspecific resistance. As they perform their protective functions, monocytes prevent dissemination of pathogenic microorganisms; they absorb and destroy endotoxins; they are involved in immunogenesis. The increase in monocyte content may be a response to the presence of unmetabolized material [8]. It is known [9] that the body's resistance to various infections diminishes during spaceflights. The blood system plays a leading role in production of defense factors in the mechanism of immunity; for this reason, one must pay attention to the demonstrated (though minor) changes in blood when subjects were exposed to ammonia in a concentration of 5 mg/m^3 with brief increase to 9.3 mg/m^3, against the background of 2.1 mg/m^3 in the sealed chamber. It should be recalled that prolonged, continuous exposure to ammonia in a concentration of 2 mg/m^3 does not elicit appreciable changes in blood morphology.

Thus, our study of the effects of low concentrations of ammonia, differing in magnitude, on hemopoiesis enabled us to demonstrate concentrations that do (5 mg/m^3 with brief increase to 9.3 mg/m^3 against the background of 2 mg/m^3) and do not (2 mg/m^3) affect the blood system.

These findings can be used in evaluating the level of safe deviation, and can be taken into consideration for validating maximum permissible concentrations in the case of man's continuous and long-term contact with low amounts of ammonia in the atmosphere of confined environments.

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UDC: 612.127.2-08:612.014.421

PERCUTANEOUS MEASUREMENT OF PARTIAL OXYGEN TENSION AND LOCAL BLOOD FLOW IN MAN DURING ORTHOSTATIC TEST

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 8 Sep 81) pp 41-44

[Article by O. Ye. Ozerova, N. M. Asyamolova and A. K. Kochetov]

[English abstract from source] Using a Drager oximeter (the FRG) modified by a Clark polarographic electrode, transdermal measurements of partial pressure of oxygen ($p_{td}O_2$) and local blood flow (Q) were carried out in 46 test subjects during tilt tests (20 min). As a result of blood redistribution, at minute 1 Q increased significantly in the lower body ($p<0.01$) and decreased in the upper body ($p<0.01$). Regardless of the sensor location, $p_{td}O_2$ increased in most cases.

[Text] At the present time the method of measuring percutaneous oxygen tension ($p_{pc}O_2$) has gained wide popularity. In order to obtain $p_{pc}O_2$ values that are close to partial oxygen tension in arterial blood (p_aO_2) local cutaneous hyperemia is used under the electrode. Evans and Naylor [1] used for this purpose injections of vasodilating agents (derivatives of nicotinic acid), histamine ionophoresis and ultraviolet light. Direct heating of the skin by devices built into an electrode constituted further development of this method [2, 3]; in essence this is a Clark polarographic electrode with heater.

The coefficient of correlation of $p_{pc}O_2/p_aO_2$ is in the range of 0.70-0.98 in a normoxic gas environment, in both healthy newborn infants and essentially healthy adults [4-11]. According to the data of Dennhard and Kobuliya [4, 11], $p_{pc}O_2$ is an average of 10-12% lower than the corresponding values for p_aO_2. Peabody et al. [9] observed that the coefficient of correlation remains high and relatively stable with considerable fluctuations of hematocrit and arterial pressure.

Thus, in the opinion of most researchers, the orientation of changes in $p_{pc}O_2$ reliably reflects the dynamics of p_aO_2 at normal barometric pressure.

Our objective here was to explore the possibility of using transcutaneous oximetry on man when testing orthostatic stability.

Methods

The percutaneous method of testing $p_{pc}O_2$ was used with a Drager (FRG) oximeter on 46 essentially healthy men ranging in age from 26 to 45 years. The sensor consisted of a modified Clark polarographic electrode, which had a platinum cathode, silver anode, electrolyte and a diaphragm. A heating device consisting of a thermistor and heating element was built into the electrode. The heating system made it possible to generate a constant local skin temperature on the surface on the order of 43°C with sensory temperature of 45°C [7], which is sufficient to obtain maximum possible vasodilatation of subepidermal capillaries in the region examined and arterialization of blood under the electrode. Molecular oxygen diffuses through the avascular epidermis and electrode diaphragm. Partial pressure thereof is determined by the polarographic method. The range of $p_{pc}O_2$ readings was 0 to 120 mm Hg, or 0 to 240 mm Hg, depending on adjustment of the instrument; sensory temperature was 45°C.

As indicated by Fenner et al. [12], the signal from the oxygen sensory is reduced because, on the one hand, the skin may be considered a second Clark diaphragm [membrane] and, on the other hand, there is absorption of oxygen by the avascular layer of epidermis. The reduction of the signal is compensated by local hyperemia produced by the electrode heating device, and in addition to the above effects this leads to a right shift of the curve of oxyhemoglobin dissociation. This releases a certain amount of oxygen, which is not absorbed in the course of tissular metabolism, and $p_{pc}O_2$ artificially rises. For this reason, the coefficient of correlation, $p_{pc}O_2/p_aO_2$ is, as we have indicated above, rather high. In view of absorption of oxygen by the avascular epidermis, it is necessary to place the sensor on skin with thin epidermis and good capillary blood flow.

Using the same electrode, we recorded concurrently the relative index of local perfusion (Q) which is closely related to arterial pressure. The measurement principle consists of the fact that the instrument records the energy expended to keep electrode temperature at 45°C. Changes in blood flow under the electrode lead to change in set temperature of the sensor; the magnitude of energy required to compensate for this change is recorded on tape in arbitrary units (scale range is 0 to 20 and 0 to 40 arbitrary units), and it is used as the relative indicator of local perfusion. Preliminary calibration of the electrode is done in vitro with atmospheric air and blank solution. The sensor was attached to the skin with adhesive rings. A heat-insulating cap was placed on the sensor, attaching it to the skin with adhesive tape, which diminished the effect of ambient temperature.

We conducted the studies during the passive orthostatic test (table tilted to +80°) with the subjects in horizontal position, for 20 min and in the aftereffect period. We periodically measured heart rate and arterial pressure during the orthostatic test. The data were submitted to statistical analysis by the method of Student.

We conducted two series of studies. In the first (24 people) the sensor for recording $p_{pc}O_2$ and Q was placed in the subclavian region and in the second (22 people) on the internal aspect of the lower third of the thigh.

Results and Discussion

Figure 1 illustrates the overall changes in $p_{pc}O_2$ obtained during orthostatic tests. As can be seen in Figure 1, the dynamics of $p_{pc}O_2$ were the same in both series of studies. In the 1st min of vertical position, the $p_{pc}O_2$ increment, as compared to background values (horizontal position) constituted 7.8±0.9 mm Hg ($p<0.01$) in the first series and 9.0±0.8 mm Hg ($p<0.01$) in the second (mean $p_{pc}O_2$ in horizontal position constituted 69.7±1.8 and 70.4±1.4 mm Hg, respectively). After the subject moved to horizontal position there was drastic drop of $p_{pc}O_2$ and it showed virtually no difference from control values by the end of the 1st min.

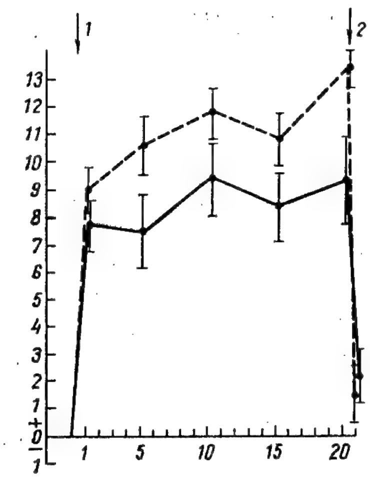

Figure 1.

Dynamics of $p_{pc}O_2$ during orthostatic test; x-axis, test time (min); y-axis, changes in values of $p_{pc}O_2$ in relation to base level (mm Hg). Here and in Figure 3: arrowhead 1--subject changes to vertical position; arrowhead 2--change to horizontal position; solid line--first series of studies; dash line--second series

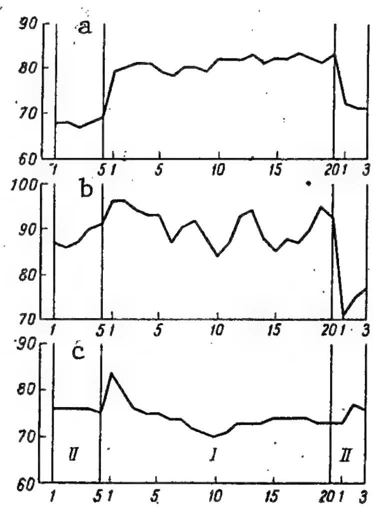

Figure 2.

Individual variants of $p_{pc}O_2$ in 1st and 2d series of studies during orthostatic test; x-axis, test time (min); y-axis values of $p_{pc}O_2$ (mm Hg)

I) subject in vertical position
II) horizontal position
a) rise of $p_{pc}O_2$ during test
b) undulant dynamics of $p_{pc}O_2$
c) decline of $p_{pc}O_2$ after rise

Individual variants of changes in $p_{pc}O_2$ during the orthostatic test, which were inherent in both the first and second series of studies, are illustrated in Figure 2. In 32 out of the 46 subjects, $p_{pc}O_2$ only rose during the orthostatic test (see Figure 2a), in 10 this parameter fluctuated (see Figure 2b) and in only 4 subjects $p_{pc}O_2$ gradually declined after an initial rise, and by the end of the test it was below background levels (see Figure 2c).

Thus, the results indicate that, during the passive orthostatic test, most subjects showed elevation of $p_{pc}O_2$, regardless of location of sensor; with the change to horizontal position this parameter came close to the base level.

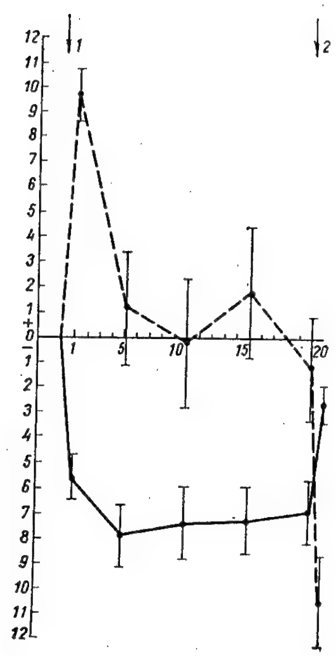

Figure 3.
Dynamics of Q in subjects during orthostatic test; x-axis, changes in Q as related to base level (arbitrary units); y-axis, time of test (min)

Concurrently with $p_{pc}O_2$, we recorded Q in arbitrary units. Figure 3 illustrates the averaged dynamics of Q during the orthostatic test in the first and second series of studies. As can be seen in Figure 3, maximum changes in Q were demonstrated in the 1st min of the test. In the first series, Q declined by the end of the 1st min in all subjects, by an average of 5.6±0.8 arbitrary units ($p<0.01$), as compared to the base values; in the second series, Q had increased by this time by a mean of 9.8±1.0 arbitrary units ($p<0.01$) in all cases. A maximum value of Q was demonstrated on the average in the 5th min of orthostatic position when the sensor was in the subclavian region, and it was 7.8±1.2 arbitrary units lower than background values ($p<0.01$); in the 20th min it was 6.8±1.2 arbitrary units lower ($p<0.01$). When the sensor was in the region of the thigh, maximum Q was found at the end of the 1st min of the orthostatic test, after which this parameter dropped abruptly to the base level.

Consequently, the dynamics of Q during the orthostatic test differed in the upper and lower half of the body: Q decreased in the subclavian region in the 1st min of the test and increased in the region of the thigh. When the subjects changed to horizontal position, Q increased in all cases, in the first series of studies, and was 4.2±0.7 arbitrary units higher than the value obtained in the 20th min of orthostatic position ($p<0.01$). In the second series, when the subjects changed to horizontal position, the opposite was observed. Thus, Q diminished by 9.2±1.8 arbitrary units in all subjects by the end of the 1st min, as compared to the last minute of orthostatic position ($p<0.01$), and it was considerably lower than base levels.

During the orthostatic test, systolic arterial pressure dropped by a mean of 11.0±1.1 mm Hg and increment of diastolic pressure constituted 11.0±0.9 mm Hg; pulse increased by 19.0±1.2 beats/min. It should be noted that we failed to demonstrate a link between the dynamics of these parameters and changes in $p_{pc}O_2$ and Q during the orthostatic tests.

The cause of the above changes in $p_{pc}O_2$ during the orthostatic test may apparently be related to development of moderate hyperventilation, which raises p_aO_2 and is an adaptive reaction. The undulant changes in $p_{pc}O_2$ or moderate decline of this parameter toward the end of the orthostatic test is indicative of individual distinctions of neurohumoral regulation of respiration under orthostatic conditions. This is confirmed by studies of several authors [13, 14] who demonstrated that, in testing orthostatic stability, subjects presented

not only an increase in minute volume of ventilation, but rare cases of development of hypoventilation.

The dynamics of Q are probably determined by redistribution of blood in the skin and subdermal tissues during orthostatic tests. This explains the difference in direction of changes in this parameter in the top and bottom half of the body.

To sum up the foregoing, it should be stated that the absolute noninvasiveness of the method and feasibility of continuous observation of dynamics of $p_{pc}O_2$ and vascular reactivity give us every grounds to consider this method promising for long-term physiological studies in aviation medical expertise.

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UDC: 629.78:612.452

ACTIVITY OF RAT ADRENAL MEDULLA AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 24 Jul 81) pp 44-47

[Article by R. Kvetňansky, P. Blažicek and R. A. Tigranyan (CSSR, USSR)]

[English abstract from text] After a 18.5-day space flight on Cosmos-1129 rat adrenals were investigated for the concentration of catecholamines and activity of enzymes involved in their synthesis, i.e., tyrosine hydroxylase, dopamine-β-hydroxylase, and phenyl ethanol amine-N-methyl transferase. It was found that inflight the sympatho-adreno-medullary system of rats was not exposed to a prolonged or strong stressogenic effect. Postflight the rats showed an increased reactivity to the immobilization stress.

[Text] Catecholamine (CA) secretion from the adrenal medulla is one of the main indicators of a stress reaction. It was shown that in earth's gravity an intensive and acute stress factor ["impulse"] leads to significant decline of epinephrine content in the medullary layer of the rat adrenals [1]; chronic or recurrent intensive stressors lead, on the contrary, to increase in adrenal CA content [1] due to increased CA biosynthesis in the adrenals [2] and increased activity of CA-synthesizing enzymes--tyrosine hydroxylase (TH), phenyl ethanolamine-N-methyltransferase (PNMT) [3] and dopamine-β-hydroxylase (DBH) [4]. Determination of the stressogenic effect of weightlessness on activity of the sympathoadrenomedullary system (SAS) was the subject of our studies in experiments on rats aboard the Cosmos series of biosatellites. It was shown [5, 6] that the SAS was not appreciably activated after 18.5 and 19.5-day spaceflights (Cosmos-782 and Cosmos-936 biosatellites); however, the results of these studies did not answer the question of whether or not prolonged weightlessness is an intensive stressor. We tried to find an answer to this question by conducting an experiment aboard Cosmos-1129 biosatellite.

The experiment aboard Cosmos-1129 was planned on the basis of our preceding results, which were obtained on rats submitted once or more times to stress on earth [1-4]. If we assume that, during a spaceflight, the animals are under the influence of intensive chronic stress, they should react to immobilization stress on earth after the spaceflight just like rats submitted

to prolonged stress. If, however, the spaceflight did not constitute a lengthy and intensive stressogenic factor for them and their SAS, these rats should react to immobilization stress on earth after the flight like animals submitted to stress for the first time.

Methods

These studies were conducted on male Wistar SPF rats (Bratislava, CSSR), flown aboard the Cosmos-1129 biosatellite for 18.5 days in space. The animals were decapitated immediately after landing (within 6-8 h) and on the 6th postflight day. Some of the animals to be decapitated on the 6th postflight day were submitted to immobilization stress for 150 min/day for 5 days, and they were sacrificed immediately after the last immobilization. They were first immobilized at the landing site, immediately after the flight, then on the 3d, 4th, 5th and 6th postflight days. Control and synchronous groups of rats were also submitted to repeated immobilization stress on an analogous program.

We assayed CA concentration [7], TH activity [8], DBH [9] and PNMT [10] in the rat adrenals.

Results and Discussion

The results of these studies revealed that epinephrine content (Figure 1), activity of TH (Figure 2), DBH and PNMT (see Table) in the adrenals of animals decapitated immediately after landing did not change, as compared to parameters of the control and synchronous groups. The only exception was a reliable increase in DBH activity of flight animals, as compared to the synchronous control (see Table). These indicators also did not change, as compared to the vivarium control and synchronous experiment, in flight rats sacrificed on the 6th postflight day. The only exceptions were a reliable increase in TH activity, as compared to parameters for the synchronous experiment (see Figure 2) and reliable increase in DBH activity, as compared to both control groups (see Table). However, when the rats were submitted to intensive immobilization stress five times after the spaceflight, in the recovery period, they presented a significant decrease in epinephrine content (see Figure 1) and appreciable increase in TH activity (Figure 2) in the adrenals, as compared to parameters of animals in the control and synchronous groups also submitted to immobilization stress.

The SAS indicators we used (catecholamines and CA-synthesizing enzymes in rat adrenals) were studied during space experiments aboard Cosmos-782 and Cosmos-936 biosatellites; the results of these studies revealed that there was no appreciable change in activity of the adrenal medulla during the period of almost 20 days in spaceflight [5, 6]. There was only a slight, reliable increase in TH activity in the experiment aboard Cosmos-782 [5], which indicated that the rats had been submitted to stress for a certain time. It was not possible to ascertain whether it was weightlessness or factors related to landing of the biosatellite, or manipulations on earth that affected them. We expected to have an answer to this question from the results of experiments aboard Cosmos-1129, in which the rats were submitted to repeated stress on earth after the spaceflight. There was no change in epinephrine content or TH activity in the adrenals of rats decapitated immediately after landing.

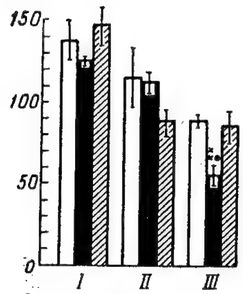

Figure 1.
Epinephrine content (nM) in rat adrenals

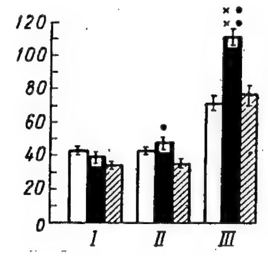

Figure 2.
TH activity (nM/h) in rat adrenals

In both figures mean values on 6-7 animals are given; white columns--vivarium control; striped--synchronous experiment; black--flight; I--at landing site; II--6 days after landing; III--6 days after landing + immobilization. × indicates $P<0.01$, as compared to parameters of vivarium control animals; the dots indicate $P<0.01$, as compared to synchronous experiment.

Activity of CA-synthesizing enzymes in rat adrenals

Time after landing	Group	DBH, nM/h	PNMT, pM/h
6-8 h (n = 7)	V_1	381±25	224±11
	F_1	365±23[a]	211±14
	S_1	250±31	197±12
6 days (n = 6)	V_2	287±15	234±10
	F_2	371±31[a,6]	218±13
	S_2	294±10	210±13
6 days + immobilization (n = 7)	V_3	394±52	247±12
	F_3	4[illegible]9±48	246±8
	S_3	378±18	239±10

Key:
- V) vivarium control
- F) flight
- S) synchronous experiment
- a) $P<0.05$, as compared to synchronous group
- b) $P<0.05$, as compared to control group

This indicated that, during the space flight, the rats were probably not exposed to any chronic stressogenic factor. It should be noted that adrenal TH activity is a sensitive indicator of the positive effect of a stressor, as evidenced by the increase thereof (by several times) following chronic or recurrent use of various stressors [3, 11-14]. Thus, for example, repeated immobilization led even to 3-4-fold increase in TH and DBH activity in the rat adrenals [3,4]. On the other hand, the spaceflight lasting almost 20 days had no effect on TH activity of adrenals in rats flown aboard Cosmos-936 [6] and Cosmos-1129. It could have been assumed that TH and DBH activity increased at the early stages of spaceflight and that adaptation occurred in subsequent phases of flight, i.e., gradual return of TH activity to the control level. However, this is unlikely, since it required almost 14 days, with a half-period of about 3 days, for TH activity to decrease to the initial level in rats submitted to immobilization 7 times [3]. The same half-period for return of increased TH activity to the base level was observed following chronic cold stress [15]. It should be recalled that, in the experiment aboard Cosmos-936, the concentration of CA and activity of CA-synthesizing enzymes in the adrenals of flight animals submitted to weightlessness did not differ from values found in animals that were centrifuged in flight [6].

The results obtained from the experiment aboard Cosmos-1129 biosatellite are convincing proof of the fact that there was a more appreciable increase in activation of the adrenal medulla in response to postlanding stress in animals that spent 18.5 in spaceflight than in animals of control and synchronous groups. A comparison of the data obtained aboard Cosmos-1129 to the results of our studies of immobilized rats [1-4] confirms the assumption that there was no prolonged and intensive stressogenic factor affecting SAS activity in the course of the spaceflight. The fact that animals reacted more after landing to immobilization stress indicates that some factor affected them during the spaceflight (perhaps weightlessness), which sensitized SAS reactivity to intensive stress on earth. Evidently, this is attributable to heightened reactivity to stress as a result of diminished requirements of the body with regard to SAS activity in a weightless state. We consider demonstration of increased reactivity to stress after the spaceflight to be a rather important factor, which must be taken into consideration in the readaptation period.

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UDC: 629.78:612.751.1

STEREOLOGICAL ANALYSIS OF RAT BONE TISSUE AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 30 Jun 81) pp 47-49

[Article by A. A. Prokhonchukov and V. S. Peschanskiy]

[English abstract from source] Stereological measurements of volume fractions of 53 samples of compact and spongy structures of bones of 15 rats were carried out. The measurements were performed on cortical lamellae, trabecules and lacunae, channels of osteons and matrices of femoral, tibial and fibular bones of rats. Postflight no significant changes were seen in the above parameters as compared to the vivarium controls. During readaptation to 1 g a slight increase in the volume fraction of spongy bones was noted.

[Text] Exposure to spaceflight factors is associated not only with biochemical, but structural changes in bone tissue, which are manifested by slowing of enchondral and periosteal osteogenesis [1, 2], osteoporosis of spongy bone and perilacunal osteolysis of compact bone [3, 4]. It is difficult to record these changes by light optic or even electron microscopy, and it is not without elements of subjectivity, sometimes yielding contradictory results [4]. Moreover, the traditional variants of these techniques do not permit quantitative evaluation of the demonstrated changes in bone tissue.

We undertook this study in the belief that stereological analysis may be more sensitive and objective than descriptive methods of morphological study, and in the event of demonstration of changes it would permit quantitative assessment thereof.

Methods

We submitted 53 samples of bone tissue from three groups of rats (a total of 15 animals) to stereological analysis by the point count method: vivarium control, first and second flight groups. The proximal metaphyses of the femur, proximal epiphyses of the tibia, as well as fibula, were decalcified in alkali-neutralized (NaOH) 10% EDTA solution and imbedded in paraffin. Sections 7-8 μm in thickness were stained with hematoxylin-eosin and picrofuchsin

according to Van Gieson. The sections were so prepared as to traverse the central segments of fragments examined, as parallel as possible to the axis of the bone involved. We also made cross sections of the fibula on the level of the diaphysis.

Stereological analysis of spongy bone (proximal metaphyses of the femur, epiphyses of the tibia) was performed using an MBS-1 microscope at magnification of 32×, with a square ocular grid of 16×16 lines. We measured 3-dimensional ["volumetric"] fractions of bone tissue ($V_{\upsilon bt}$) and bone marrow ($V_{\upsilon bm}$) by counting points (grid intersections ['nodes," or "units"]) referable to profiles of bone structures. We considered both trabeculae and the cortical lamella as bone tissue, and in the tibial epiphysis--the subchondral lamella of the articular surface also. We examined the entire preparation, for which it was arbitrarily divided into two and occasionally three successively examined sections. Each section was examined in 2-3 arbitrary positions of the grid so that the total number of points counted would be close to 500. Most often there were more points counted, so that the relative margin of error was less than 5% [5].

Analysis of compact bone (longitudinal and cross sections of fibular diaphysis, cortical lamella of the heck of the femur) was made using an MBI-6 microscope at magnification of 200× with a square 17×17 line ocular grid. We measured 3-dimensional fractions of osseous lacunae ($V_{\upsilon ol}$), osteon canals ($V_{\upsilon oc}$) and organic matrix ($V_{\upsilon om}$). We examined 4-5 successive fields so that there would be close to 100 total points counted per preparation.

Considering the fact that the thickness of the sections was commensurate with the diameter of osseous lacunae and osteon channels, the 3-dimensional fraction of both was measured on the basis of maximum area of their outline, by means of refocusing. Abiding by this condition enables us to compare the obtained results without resorting to corrections for the Holmes effect [5, 6], which requires extremely time-consuming measurements. The obtained digital data were submitted to statistical processing, and determination was made of Student's criterion.

Results and Discussion

We failed to demonstrate quantitative manifestations of osteoporosis or resorption of bone tissue in the material examined. Moreover, we observed some enlargement of volumetric fraction of bone tissue in spongy bone of flight rats, as compared to the vivarium control, as well as in animals of the second flight group, as compared to the first. However, the differences were extremely small and statistically unreliable ($P<0.05$). The insignificant differences in volumetric fractions of osseous lacunae, osteon canals and compact bone matrix in animals of the groups examined were also found to be statistically unreliable (see Table).

In essence, the results of these studies coincide with data obtained from the experiment aboard the Cosmos-936 biosatellite [7] and differ somewhat from bone tissue parameters of man after flight aboard the Salyut-1 space orbital station, when some decrease in density of spongy substance of some skeletal

Stereological parameters of bone, % (M±m)

Object and stereological parameter	Animal group		
	vivar. control	first flight	second flight
	Spongy bone		
Proximal metaphysis of femur	(n=5)	(n=6)	(n=3)
$V_{v bt}$	52,22±2,74	53,45±1,11	54,80±0,92
$V_{v bm}$	47,78±2,74	46,55±1,11	45,20±0,92
Proximal epiphysis of tibia	(n=7)	(n=4)	(n=6)
$V_{v bt}$	42,66±2,28	43,48±2,91	48,27±1,92
$V_{v bm}$	57,34±2,28	56,52±2,91	51,73±1,92
	Compact bone		
	(n=7)	(n=8)	(n=7)
$V_{v ol}$	10,61±0,61	9,50±0,71	104,1±0,53
$V_{v oc}$	4,21±0,57	3,08±0,61	4,65±0,91
$V_{v om}$	85,18±0,94	87,42±1,13	85,21±1,02

bones [8] was observed, with retention of their microscopic structures [9]. These facts, when submitted to thorough analysis and comparison, do not contradict one another, since the changes in metabolic processes demonstrated in human and animal bone after spaceflights involve labile metabolic components and do not have an appreciable effect on more stable tissues that form the morphological structure. This assumption is clearly confirmed by the data pertaining to restoration of metabolic parameters, which had been impaired in flight, during the period of animal adaptation (20th-26th day) to conditions on earth.

The method of stereological analysis of bone tissue, which we used, was found to be quite effective for quantitative evaluation of the condition of rat bones after the spaceflight, and it can be well-used for the purposes mentioned. This is indicated, in particular, by the reliable coincidence of measurement of volumetric fraction of vascular canals of compact and spongy bone structures to analogous data obtained by means of direct measurements [8, 10].

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UDC: 629.78:612.398.192

CHANGES IN RAT TISSUE DEOXYRIBONUCLEOPROTEIN AND NUCLEIC ACIDS FOLLOWING FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 24 Jul 81) pp 49-52

[Article by E. Mišurova, R. A. Tigranyan, T. Sabova and M. Praslička (CSSR, USSR)]

[English abstract from source] The concentration of polydeoxyribonucleotides and nucleic acids was measured in the spleen, thymus, liver, bone marrow and blood of rats flown for 18.5 days on Cosmos-1129. The exposure led to an increase in the polydeoxyribonucleotide content in the thymus and a decrease of the DNA and RNA concentration in the spleen and thymus. These changes returned to normal at R+6.

[Text] The studies we conducted on Cosmos-782 and Cosmos-936 biosatellites revealed that several hours after returning to earth the rats presented a significant elevation of polydeoxyribonucleotide (PDRN) levels [1, 2]. PDRN are fragments of deoxyribonucleoprotein (DNP), i.e., oligonucleosomes [3], and for this reason their level rises with degradation of DNP. These changes were demonstrated only in lymphatic and hemopoietic organs, just as was the case under the effect of some physicochemical factors [4, 5, 6]. In all instances, PDRN level rose starting in the 2d h and reached a maximum in the 4th-8th h, then returned to normal. On the basis of these findings, we assumed that the elevated PDRN level found in the experiments aboard Cosmos-782 and Cosmos-936 biosatellites in the 6th-10th postflight hour was due to damage to part of the DNP, which occurred at the final stage of the flight. In addition to DNP changes, we demonstrated a marked decrease in nucleic acid content of the spleen and thymus of rats in the flight group. Most of the changes were restored to the base values within 25 days of the readaptation period [1, 2].

We studied here the process of recovery from these changes in greater detail, mainly on the basis of the reaction to an additional stress factor.

Methods

These studies were conducted on male Wistar-SPF (Bratislava, CSSR) rats flown for 18.5 days in space aboard Cosmos-1129 biosatellite. The animals were sacrificed 6-8 h after landing and on the 6th postflight day. Some of the animals

sacrificed on the 6th postflight day were submitted to immobilization stress five times (150 min/day); the control and synchronous groups of rats were also submitted to repeated immobilization stress. We assessed DNP changes on the basis of assays of soluble PDRN and DNA (as part of DNP) [7]. RNA and DNA were assayed by the method of R. G. Tsanev and R. G. Markov [8]. The obtained data were submitted to processing by the method of variation statistics [9].

Results and Discussion

PDRN level in the spleen of the flight group of rats was within the normal range after the flight and did not differ from the level demonstrated in animals of control groups. The reduction in mass of this organ was associated with a decrease in nucleic acid content, chiefly DNA. In rats of the synchronous experiment, PDRN level, spleen mass and nucleic acid content did not differ from findings in vivarium control animals. Changes elicited by spaceflight factors were restored within 6 days of the readaptation period. However, the reaction to repeated immobilization stress differed in flight animals from the reactions of vivarium control and synchronous experiment animals. The difference consisted of the fact that the PDRN level rose significantly (by almost 2.5 times) in flight rats submitted to stress, whereas the reduction in mass of the organ was related to the marked decrease in nucleic acid content (Figure 1)

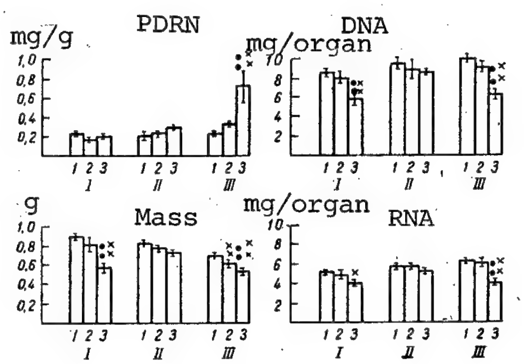

Figure 1.
PDRN level, DNA, RNA content and spleen mass (means of 6-7 readings)

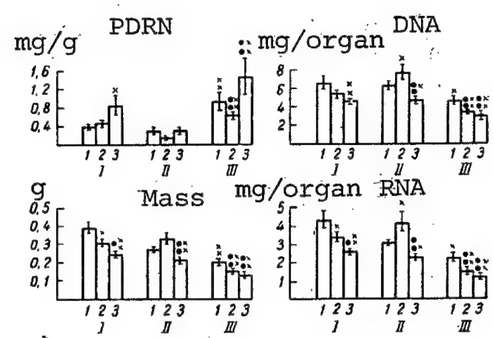

Figure 2.
PDRN level, DNA and RNA content and weight [mass] of thymus

Key for Figures 1, 2, 3 and 4:

1) vivarium control
2) synchronous experiment
3) flight
I) immediately after landing
II) 6 days after flight
III) 6 days after flight and immobilization

x) reliability of difference in relation to vivarium control $P<0.05$ immediately after and 6 days after experiment

xx) reliability of difference in relation to vivarium control immediately and 6 days after experiment is $P<0.01$

•) in relation to synchronous control at same periods $P<0.05$

••) in relation to synchronous control at same periods $P<0.01$

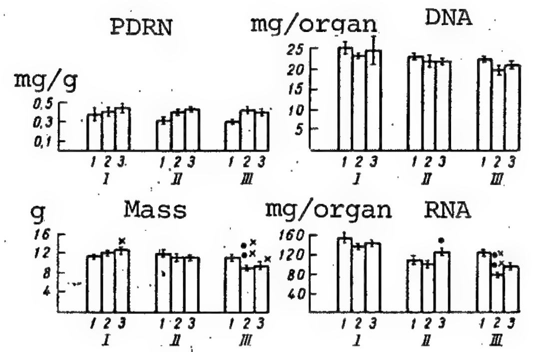

Figure 3.
PDRN level, DNA and RNA content, and mass of liver

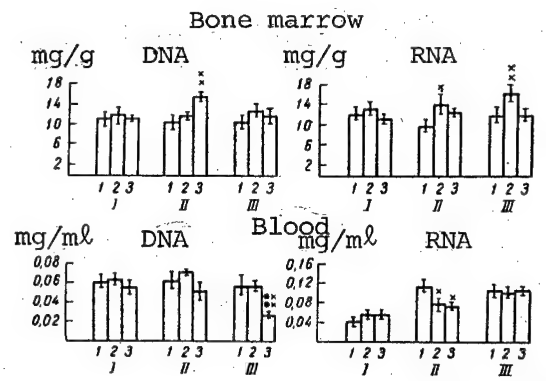

Figure 4.
Concentration of DNA and RNA in bone marrow and blood

Immediately after flight rats landed, PDRN of the thymus was almost double the level in vivarium and synchronous control animals, and thymus mass diminished; DNA and RNA content decreased by 40%, as compared to the vivarium control. This decline constituted only 20% in the synchronous experiment animals. After 6-day readaptation, PDRN level of flight animals did not differ from that of control groups of animals; however, mass of the thymus and nucleic acid content did not recover. In the rats used in the synchronous experiment, DNA and RNA content increased, exceeding even the level in the vivarium control. The changes caused by immobilization stress were similar in all groups of animals and consisted of significant elevation of PDRN, decrease in nucleic acid content and weight of the organ (Figure 2).

We failed to demonstrate appreciable changes in PDRN level, nucleic acid content or weight of the liver of animals in the flight and synchronous experiment groups, both immediately after the experiment and on the 6th day of the readaptation period. Immobilization stress elicited a decrease in RNA content and weight of this organ in the flight and synchronous groups of rats, but had no appreciable effect on these parameters in the vivarium control animals (Figure 3).

We found no changes in nucleic acid concentration in the bone marrow of the flight and synchronous groups of animals immediately after the experiment. After 6 days, the flight animals had a higher concentration of DNA than the control level, whereas nucleic acid concentration did not change under the influence of immobilization stress, with the exception of some increase in RNA concentration in synchronous control animals (Figure 4).

No changes were noted in nucleic acid concentration in the blood of animals of the flight and synchronous groups immediately after the experiment; however, 6 days later, RNA concentration was decreased in both these groups, as compared to the vivarium control. As a result of immobilization stress, DNA concentration decreased in the flight group, whereas RNA concentration did not change (see Figure 4).

The changes in DNP and nucleic acids demonstrated immediately after Cosmos-1129 landed were essentially the same as in animals used in the Cosmos-782 and Cosmos-936 experiments [1, 2]. The only exception was lack of increase in PDRN level in the spleen. It can be assumed that, under the conditions of this experiment, there were cells that reacted by causing dissociation of DNP, i.e., mainly lymphocytes and erythroblasts which had been removed from the spleen during the flight. Restoration of all tested parameters occurred within the first 6 days of the readaptation period in the spleen of rats flown aboard Cosmos-1129. Such rapid recovery of nucleic acid content in this organ indicates that the decrease in DNA and RNA content, which was noted several hours after landing, was the result not only of degradation of sensitive cells and inhibition of hemopoiesis [10], but temporary increase in discharge of leukocytes from the spleen, which could be mediated, in particular, by catecholamines [11].

Examination of rats submitted to repeated immobilization stress revealed that spleen DPN in the flight group of animals was more sensitive to this additional burden, since signs of degradation thereof (i.e., elevation of PDRN level) and concurrent decrease in nucleic acid content were found only in this group of animals.

DNA and RNA content of the thymus was not restored within 6 days after landing; however, the reaction to repeated stress was similar to that of rats used in the synchronous experiment and vivarium control.

No appreciable changes in the parameters under study were demonstrated in the liver, bone marrow and blood of flight rats. A decrease in DNA concentration was noted in bone marrow and, mainly, blood after immobilization stress, and it was more marked in the flight group of rats. The changes in DNA concentration in blood correlated, to some extent, with change in lymphocyte count demonstrated in the same animals (data of L. V. Serova). There were mild changes in RNA concentrations in bone marrow and blood after repeated use of stress. Repeated stress caused a decrease in RNA content of the liver to the same extent in the rats in the flight group and synchronous experiment, which may be indicative of diminished compensatory capabilities of the liver as a result of 18.5-day hypokinesia in flight or during the synchronous experiment.

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UDC: 629.78:612.766.2-08:612.44

MORPHOLOGICAL DISTINCTIONS OF MACACA RHESUS MONKEY THYROID UNDER NORMAL AND VARIOUS TYPES OF HYPOKINETIC CONDITIONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 17 Aug 81) pp 52-58

[Article by G. I. Plakhuta-Plakutina, Ye. A. Savina, G. S. Belkaniya, D. S. Tavadyan, N. P. Dmitriyeva, Ye. A. Amirkhanyan and R. S. Smirnova]

[English abstract from source] Thyroid glands and C cells of Macaca rhesus were examined histologically, electron microscopically and morphometrically. The examinations were performed on 6 intact and 7 hypokinetic rhesus monkeys which were kept in a suspension device for 2 months, small cages for 2 months or in a head-down position (7 days in a horizontal position and then 11 days in a head-down position at -6°). The experiment with a diminished motor activity and a normal support function of the lower limbs (maintenance in small cages), in spite of its long duration, produced no structural changes in the parenchyma or C cells. The 18-day bed rest test was followed by a hypofunction of the thyroid gland, inhibition of hormonal synthesis and secretion without distinct changes in C cells. Unlike previous experiments, the suspension study led to hyperplasia and hypertrophy of C cells and increase of their nuclear volume. Activation of C cells can be regarded as an adaptive reaction aimed at stabilizing bone calcium.

[Text] Investigation of mechanisms of impairment of calcium metabolism, which is consistently observed in man and animals in weightlessness and under hypokinetic conditions, is one of the pressing tasks for space biology and medicine. The C cell system of the thyroid, which produces calcitonin, is considered to play a major role in hormonal regulation of calcium metabolism. Morphological signs of diminished functional activity of the thyroid, including C cells, were found in animals following flights aboard biosatellites. We were unable to find any reports dealing with investigation of the reactions of these cells under hypokinetic conditions in the literature available to us. Our objective here was to study the thyroid of monkeys whose motor activity was restricted and load on the posterior limbs was diminished.

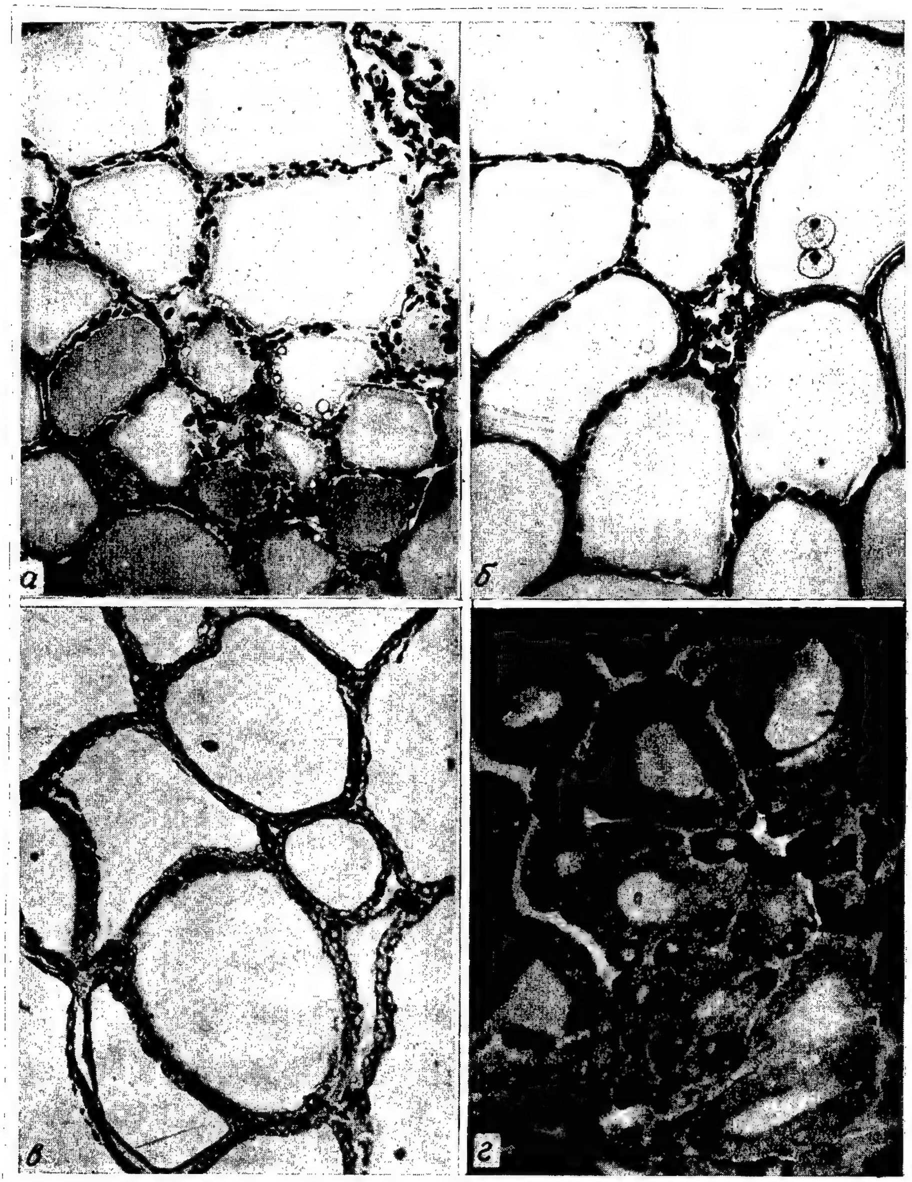

Figure 1. Thyroid gland and C cells of intact and experimental monkeys

а) control; hematoxylin-eosin stain; magnification 200×
б) 18th day of AOH; elongated follicles, flattened epithelium; hematoxylin-eosin stain; magnification 200×
в) control; distribution of C cells; Grandi method; magnification 200×
г) use of suspension unit; 2 months; proliferation and hypertrophy of C cells; Grandi method; magnification 400×

Methods

We conducted this study on 13 Macaca rhesus monkeys (males) 3.5-5 years of age. Two monkeys were kept for 2 months on a suspension unit ["diminished support stand"], which enabled us to reduce the load on the hind legs to 1/6 G (the model of this unit was proposed and described by G. S. Belkaniya et al.) [1], while 2 other animals were kept in small cages (hypokinesia) for the same period of time. In another experiment (on 3 monkeys) we reproduced a model of antiorthostatic hypokinesia (AOH), which was developed for use on monkeys [2], the animals first spending 7 days in horizontal position and then 11 days in antiorthostatic position, with a tilt angle of -6°. Four monkeys, kept unrestricted in a large pen and two kept in cages in the vivarium served as a control. The thyroid gland was weighed; one lobe was used for histological examination and the other for electron microscopy. Pieces of tissue taken from different parts of this organ were fixed in 2% glutaric aldehyde (pH = 7.4) with subsequent additional fixing in 1% OsO_4 solution, then imbedded in a mixture of araldite and epon. The sections were examined under a Geol Co. 100B electron microscope. For the histological studies, the thyroid was fixed in Bouin liquid and imbedded in paraffin. The sections were stained with hematoxylin-eosin, hematoxylin and light green, according to (Khel'mi) and by the method of Marais and Ham [3], which enabled us to differentiate between follicles that contained (blue colloid) and did not contain (yellow colloid) iodinated amino acids on the basis of tinctorial properties of colloid. We used the Grandi method for demonstration of C cells [4]. We measured the height of the follicular epithelium, counted C cells in 10 fields of vision in a random sample, at a magnification of 10×40. We measured the volume of nuclei of thyrocytes and nuclei of C cells by means of an RA-6 drafting machine, outlining the projections of 100 nuclei examined at a magnification of 2000×. The data were submitted to mathematical processing by the methods of variation statistics generally used in morphometry. Reliability of differences was determined by the criterion of Student and Fisher.

Results and Discussion

The weight of the thyroid of intact animals constituted 0.01-0.02% of body weight, which is consistent with data in the literature [5].

Histological examination of the thyroid of control monkeys showed that it consisted of medium and large irregular-shaped follicles. Areas of the section with smaller and functionally more active follicles often alternated with large follicles elongated by colloid. In most follicles, the epithelium was cuboidal; its height ranged from 4.6 to 5.4 μm. In addition, we encountered in some parts of the gland some follicles with flattened epithelium, and the incidence of such areas differed in different animals. The thyrocyte margins were well-circumscribed, the nuclei were oval and their volume constituted 67 to 83 μm^3. The colloid was eosinophilic, moderately dense, and marginal vacuoles were encountered mainly in small follicles (Figure 1*a*). There was prevalence of follicles with yellow-blue colloid (65% of the follicles) and light blue colloid in the rest.

Figure 2. Control. Thyroid; magnification 15,000×

Top--cuboid cell with elliptic nucleus (Я), large nucleolus (Як); there are many osmiophilic secretory granules (Гр) in the cytoplasm, dilated bands of granular endoplasmic reticulum (ГЭР), Golgi complex (Кг), lysosomes (Лз), microvilli (МВ) on apical margin of cells, follicular lumen (ПР). Bottom--fragment of flattened follicular cell with elongated nucleus (Я).

It is difficult to identify C cells in monkeys using the usual staining methods, unlike rats and dogs. They are distinctly demonstrable when thyroid sections are impregnated by the Grandi method. The C cells were situated mainly in the central part of the gland, parafollicularly and epifollicularly, alone or in the form of chains (of 3-4 cells) along the basal edge of the thyrocytes. Groups of 3-5 or more cells were demonstrable in interfollicular tissue (Figure 1*в*). The number of C cells per field constituted a mean of 5.2±0.7. The size and amount of secretory granules in cytoplasm varied, reflecting different stages of the secretory cycle. The volume of C cell nuclei ranged from 95 to 110 μm^3. Similar findings with regard to condition and number of these cells--4.2-4.6 (per field at magnification of 10×45)--were reported in [6, 7].

Electron microscopy revealed that the thyroid tissue of intact monkeys consisted of dilated follicles, the walls of which consisted of either flattened or cuboid cells. Some follicular cells had smooth apical margins with sparse microvilli, while others had a more significant number of microvilli. The follicular cavity contained homogeneous or granular colloid. We were impressed by the profusion of osmiophilic secretory granules of different sizes in the cytoplasm (Figure 2). We also encountered typical lysosomes with lipid inclusions among these granules. The granular endoplasmic reticulum (GER) was intensively developed, consisting of irregularly shaped dilated cavities. Golgi's complex was encountered in all cells, usually in the perinuclear region. Mitochondria were either isolated or in groups, with well-developed cristae and compact fine-grain matrix. Thyrocyte nuclei were often of an irregular shape with aggregated chromatin. In the flattened [squamous?] epithelium we observed narrow, elongated nuclei and in the cuboid cells they were of an ellipsoid shape (see Figure 2).

Analysis of the thyroid structures of intact monkeys revealed that the degree of their functional activity depended largely on upkeep conditions. In the animals kept in large pens the thyroid was more active than those kept in cages. According to the data in [8], 1-year isolation elicited thyroid hypofunction. A decline of thyroid function was also observed during long-term captivity, which is attributable, in the opinion of authors, to social stress that develops when they are kept in cages [9].

The weight of the body and thyroid after 2 months of hypokinesia did not differ from control findings. Microscopic examination revealed signs of diminished functional activity manifested chiefly by a change in tinctorial properties of colloid, since it was stained in yellow and yellow-blue shades in most follicles (80-90%). The number of C cells (5.6±0.6), their distribution, dimensions and secretory granules they contained were also close to control findings.

In two monkeys in the same series of experiments, who were kept on the suspension unit, we found a decrease in body and thyroid weight after 2 months (by 15 and 34%). The thyroid consisted mainly of oval follicles with cuboic epithelium. There were many fine de novo follicles with small lumen. Colloid was moderately compact, with marginal resorption vacuoles. We observed a change in staining properties, with prevalence of follicles containing yellow and yellow-blue colloid (in 75-80% of the follicles). Interfollicular tissue was represented by

many de novo islets, among which calcitocytes formed groups of 3 to 6-7 cells. The latter were also encountered within the thyroid follicles. C cells were at different stages of the secretory cycle, i.e., the cytoplasm was either filled with secretory granules or wanting (Figure 1e). The number of C cells in monkeys kept on the suspension stand was substantially increased (8.4±0.8) as compared to both the control ($P<0.01$) and hypokinetic animals ($P<0.001$).

After the 18-day AOH experiment, the monkeys presented morphological signs of thyroid hypofunction: low, flattened epithelium, 4.0-4.5 μm tall, with indistinct cell margins, small nuclei 66-74 μm in size, oval or elongated along the basement membrane (Figure 1б). We observed breaks in the follicular walls with extravasation of colloid into the stroma. The colloid was dense, laminated, without resorption zones and we encountered desquamated cells in it. There was prevalence of follicles with yellow and yellow-blue colloid (75-80% of the section), which is indicative of diminished production of iodinated thyroglobulins.

Electron microscopy of the thyroid of monkeys in the experimental group revealed dilated follicles, whose narrow wall consisted of elongated follicular cells. Some of the cells consisted of elongated nuclei invested in an insignificant, barely visible band of cytoplasm (Figure 3*a*). The nuclei presented aggregated chromatin and we seldom found a nucleolus. The cytoplasm revealed severe reduction of secretory osmiophilic granules, as compared to cells in an intact thyroid. We encountered less than 1-4 granules in a number of cells, whereas in others the granular component was represented only by lysosomes. In most cells, there were absolutely no secretory granules (Figure 3*a*, *б*). We observed dilated GER spaces in some cells. There were isolated mitochondria, and we rarely encountered Golgi's complex. The apical margins of most cells were smooth; occasionally we demonstrated isolated, short microvilli. In the basal part of the cells we encountered capillaries with dilated cavities, in which erythrocytes were visualized. Intensive development of elements of connective tissue was observed between some follicles (Figure 3*б*). Thus, electron microscopic findings were indicative of drastic decline of secretory activity of the thyroid of experimental monkeys.

In monkeys used in the AOH experiment, the population of C cells did not present clearcut differences from the control. There was a moderate number of C cells (4.1±1.2); they were densely filled with secretory granules, and occasionally it was difficult to distinguish between C and follicular cells. The volume of nuclei was close to the control.

Experiments with hypokinesia and variants thereof of the AOH type, as well as with the suspension unit, are models that make it possible to reproduce some of the effects of weightlessness.

In spite of the rather long duration of the experiment (2 months), restriction of motor activity with retention of support on the lower limbs (use of small cages) did not elicit appreciable structural changes in either the parenchyma or C cell system of the thyroid. The thyroid of these animals differed from the control primarily in a change in tinctorial properties of colloid, in which there was, according to its color, a decrease in amount of iodinated amino acids.

Figure 3. AOH, 18 days. Thyroid; magnification 7000×

а) elongated nuclei (Я) taking up a flattened cell almost entirely; segments of cytoplasm in the form of narrow bands around nucleus; isolated dilated GER (ГЭР) bands, no secretory granules demonstrable; isolated microvilli (MB)

б) numerous collagen fibers (KB) between follicles; isolated GER cisternae in cytoplasm, or dilated irregular shaped spaces; drastically reduced number of secretory granules (Гр); elongated, irregular-shaped nuclei

When motor activity was restricted and the animals were in horizontal position, with the head end tilted at an angle of -6° (AOH), distinct morphological signs of thyroid hypofunction were demonstrable already after 18 days. On the light level, there was flattening of epithelium, reduction in size of thyrocyte nuclei, consolidation of colloid and change in its tinctorial properties, which was indicative of decrease in iodinated thyroglobulin content. Ultrafine structure revealed inhibition of processes of synthesis and discharge of hormone. C cells were at different stages of the secretory cycle and showed no significant differences from the control. Conversely, a very distinct C cell reaction was demonstrable in monkeys kept in the suspension unit for 2 months. In addition to consolidation of colloid, decrease in iodinated thyroglobulines, the thyroid acquired a small-follicle structure with morphological signs of activation of thyroid parenchyma and marked proliferation of C cells, with increase in dimensions and volume of their nuclei.

Data in the literature indicate that, while restriction of motor activity with retention of supporting function of the limb leads to balanced slowing of osteogenesis and osteolysis, elimination of the static load elicits faster resorption of osseous tissue [10]. On this basis, the reactive changes in C cells demonstrated in the experiments using the suspension unit could be interpreted as adaptive, aimed at stabilization of bone calcium. It should be noted that the opposite reaction of the C cell system was observed in rats in weightlessness. At the earliest postflight term, the number of C cells and volume of their nuclei were reliably reduced, whereas already within 9-13 h of being in earth's gravity again there were morphological signs of increased functional activity of C cells (in response to drastic increase in load on skeletomuscular system), and after 2 days the population of these cells doubled [11, 12]. Activation of the C cell system after returning to earth's gravity is consistent with the calcium retention always observed in the postflight period [13].

Thus far, it is difficult to interpret the submitted facts, but they merit attention from the standpoint of biological role of gravity in regulating processes of calcium metabolism.

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UDC: 612.124.014.47:531.113

EFFECTS OF $+G_x$ ACCELERATION AND ADETURON ON NUCLEIC ACID CONTENT AND OTHER PARAMETERS OF MOUSE PERIPHERAL BLOOD

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 14 Apr 80) pp 58-60

[Article by M. I. Minkova, I. T. Nikolov, Ye. R. Datsov, T. P. Pantev and V. B. Tenchova (People's Republic of Bulgaria)]

[English abstract from source] The effect of acceleration and adeturon, a radioprotector, on the content of nucleic acids, the count, composition and osmotic resistance of white and red blood cells was investigated. Male mice of the H strain were exposed to $+20G_x$ for 5 min. The above parameters were measured 1, 24 and 48 hours after the exposure. The nucleic acid content decreased significantly immediately after the exposure and tended to return to normal afterwards. The leucocyte count was increased during all observation periods, and the erythrocyte count was decreased 1 hour after the exposure. Osmotic resistance of white and red blood cells varied in a different manner after the exposure. Adeturon administered at optimal protective doses (300 mg/kg) modified regulatory mechanisms of the animal body.

[Text] Accelerations elicit a number of disorders and critical states in the function of organs and vital systems of the body [3], particularly circulatory changes. There are data to the effect that, along with purely hemodynamic changes, there are serious disturbances referable to quantity, composition, morphology and physicochemical properties of formed blood elements of animals and man [1, 4, 6, 7, 10, 11], as well as changes in mitotic activity and damage to the nuclear system of bone marrow cells [4, 13].

On the other hand, the prospects of using new effective radioprotective agents in space medicine require detailed information about their influence on tolerance of nonradiation spaceflight factors. It is known that, under the difficult conditions created by radiation and other flight factors, not all of the drugs that have become established on earth can be recommended [2]. This applies entirely to radioprotective agents as well, whose effects must be tested on models that approximate real flight conditions as much as possible.

Our objective here was to test the influence of the radioprotector, adeturon, on the effects of transverse accelerations in experiments on animals.

Methods

Experiments were performed on male H mice weighing 20-22 g. The animals were put in special containers, with their head up, parallel to the axis of the centrifuge and submitted to +20 Gx accelerations (296 r/min) for 5 min. For this purpose, we used the 1963 model of a type Yanetskiy S-50 centrifuge with a 20.5 cm arm.

We gave the experimental animals intraperitoneal injections of adeturon, in a dosage of 300 mg/kg weight, 30 min before exposure to accelerations. Saline was injected to control mice under the same conditions.

We assessed the changes resulting from exposure to accelerations in the 1st, 24th and 72d hours of the aftereffect period, according to level of nucleic acids (NA), number and osmotic resistance of leukocytes and erythrocytes, and hemoglobin.

NA level was assayed by the method of Kritskiy [5]; white and red blood cells were counted by routine methods, while the HB test was used to measure the concentration of hemoglobin. Osmotic resistance of leukocytes was measured by the method of Pareyshvili et al. [8] and that of erythrocytes according to Chekurov et al. [12].

The experimental data were processed by the method of variation analysis.

Results and Discussion

We demonstrated a normal amount of NA (13.19 mg%) in blood leukocyte mass of 40 intact male mice. Intraperitoneal injection of 300 mg/kg adeturon did not alter normal NA values.

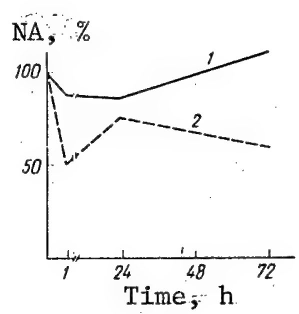

Figure 1.
NA content of mouse blood after exposure to accelerations (1) and injection of adeturon (2)

Here and in Figures 2 and 3: dots indicate reliability of result in relation to background

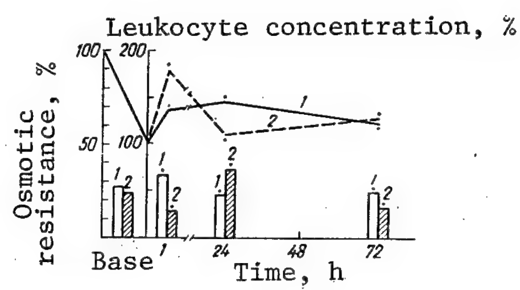

Figure 2.
Changes in leukocyte count (lines) and osmotic resistance (columns) after exposure to accelerations (1) and injection of adeturon (2)

Accelerations elicited some reliable decline of NA content (in the 1st post-experiment hour) (Figure 1). Observations up to the 72d h failed to demonstrate statistically significant deviations from normal. Administration of adeturon elicited a drastic change in effects of accelerations. NA level remained low throughout the observation period, with marked minimums (to 50%) in the 1st and 72d hours.

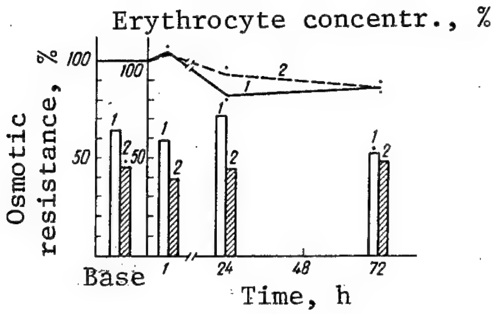

Figure 3.
Change in erythrocyte concentration and osmotic resistance after accelerations and adeturon

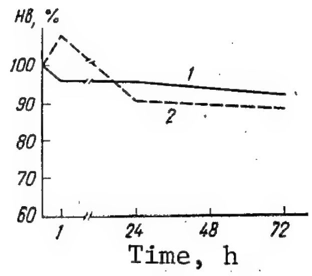

Figure 4.
Change in hemoglobin concentration in erythrocytes after accelerations (1) and adeturon (2)

The results of our study revealed that accelerations consistently and reliably increased the quantity of leukocytes in peripheral blood (Figure 2). Other authors have also reported such leukocytosis as a result of using accelerations [4, 7]. Changes in reactivity due to centrifuging were also demonstrated with regard to leukocyte osmotic resistance. After an initial rise of this parameter, in the 24th and 72d h there was already prevalence of cells with diminished resistance in peripheral blood. Preventive administration of adeturon altered the reactions. The demonstrated leukocytosis developed in waves, with a very marked peak in the 1st h and minimum at 24 h. Changes in osmotic resistance were analogous, but inversely related to leukocyte count.

In the 24th h after exposure to accelerations, we observed some increase in quantity of red blood cells and later there was persistent erythropenia (Figure 3). Osmotic resistance of cells diminished reliably only by the 72d h. Interestingly, adeturon elicited a reliable decrease in erythrocyte resistance only in intact animals. We failed to demonstrate any appreciable effect of this agent on other parameters.

Against the background of a slightly low percentage of hemoglobin in erythrocytes of control animals, we observed undulant change in its concentration in rats given adeturon (Figure 4). However, a comparison of data on quantity of erythrocytes and concentration of hemoglobin revealed that there is a correlation between these parameters.

Comparative analysis of different parameters revealed some distinctive features that are difficult to interpret. Of particular interest is the correlation

between NA content, white cell count and their osmotic resistance in the presence of adeturon. We were also impressed by the fact that in the case of marked leukocytosis with diminished cell resistance there was drastic decline of NA content and vice versa. Normalization of leukocyte count was related to a tendency toward normalization of other parameters. It would be difficult to single out the main element in this chain of disturbances. At any rate, the changes in NA content are not a function of leukocyte count. Direct damage thereof is also unlikely. The correlation between NA concentration and osmotic resistance of leukocytes warrants the belief that the observed changes are the consequence of altered resistance of NA-containing cells.

On the basis of the foregoing, it can be concluded that adeturon in optimum protective doses has a tendency toward modifying regulatory mechanisms of the body.

Experimental data have been obtained to the effect that cystamine, serotonin and other radioprotective agents lower resistance to accelerations within the first hours after administration [9]. This effect is attributed to potentiation by radioprotectors of hypoxia induced by accelerations. In view of the lack of changes in hemoglobin content of erythrocytes, it is difficult to apply this interpretation to the effect of adeturon. Additional studies are required to explain the effect it elicited.

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UDC: 612.822.3.014.426

SIGNIFICANCE OF MAGNETIC FIELD PARAMETERS TO CHANGE IN EVOKED BIOELECTRIC ACTIVITY OF THE BRAIN

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 25 Aug 81) pp 61-63

[Article by N. P. Smirnova, L. D. Klimovskaya and A. S. D'yakonov]

[English abstract from source] The effect of a constant uniform magnetic field of 0.1 to 1.6 T on the somatosensory potentials of the brain cortex and hypothalamus was investigated on nembutal anesthesized rats. The exposure increased the amplitude and modified the form of evoked potentials in both brain structures. The effect grew significantly with induction of the magnetic field. At every induction level changes in the evoked potentials of the hypothalamus were more distinct than those of the cortex. These findings were compared with the effects of a weakly pulsating magnetic field of the induction 0.1-0.4 T.

[Text] A change in bioelectric processes in the brain is referable to typical manifestations of nervous system reactions to static magnetic fields (SMF) of high intensity [1-6]. We previously demonstrated that when an animal is exposed to SMF there is an increase in amplitude and complication of shape of evoked somatosensory potentials in different parts of the brain [7]. In these studies, we used an SP-15A electromagnet, which generated SMF with a 100-Hz pulsating component, induction of which constituted 1.8% of overall field induction. The rats were exposed to total body SMF with induction of 0.05-0.4 T. The nature of changes in evoked potentials (EP) warranted the belief that they were based on biophysical mechanisms. This indicates that the physical characteristics of the magnetic field play an appreciable role. For this reason, we studied here the changes in evoked activity of the brain with exposure to a strictly static [constant, steady] homogeneous magnetic field with a higher level of induction.

Methods

In this study we used an SP-57A electromagnet with polar tips in the form of a circle with 450-mm radius and gap of 100 mm between them. The generated magnetic field was homogeneous in a radius of 380 mm, strictly static, with

vertical orientation of lines of force. Experiments were conducted on 50 white rats weighing 180-200g under nebutal anesthesia (40 mg/kg body weight, intraperitoneally). EP arising with supraliminal stimulation of the sciatic nerve were derived unipolarly by means of manganin electrodes from the sensorimotor cortex and hypothalamus and, after summation on an Atak-401 medical computer, recorded on an ink-writing machine. Thus, each recorded potential was the mean of 10 responses. EP were recorded on the same animal before exposure to the magnetic field, during (in the zone of the homogeneous field) and after exposure. In the first series of experiments, the animals (30 rats) were exposed to magnetic fields with increasing induction in the range of 0.1 to 1.6 T with total exposure time of 30 min. In the second series, 20 rats were exposed to SMF with 1.6 T induction for 15 min.

Results and Discussion

Figure 1 illustrates the typical changes in EP of the cerebral cortex and hypothalamus during exposure to SMF with induction of 0.1 to 1.6 T. We recorded biphasic, negative-positive primary responses (PR) in both brain structures before exposure to SMF. In SMF of 0.1 T, the cerebral cortex showed an increase in amplitude of PR and appearance of low-amplitude additional waves. In SMF of 0.4 T, the positive phase of PR disappeared; however, there was an increase in amplitude of additional waves. In SMF of 0.8 T, there was an increase in number of EP phases and their amplitude; in SMF of 1.6 T, amplitude of EP increased even more. During exposure to SMF, in addition to increase in PR amplitude in the hypothalamus, we observed splitting of the negative phase. As in the cortical responses, the structure of hypothalamic EP also showed appearance of additional waves, the amplitude of which increased with increase in field induction. Upon reaching induction of 1.6 T, fast, regular, high-voltage waves appeared in the place of the slow additional waves.

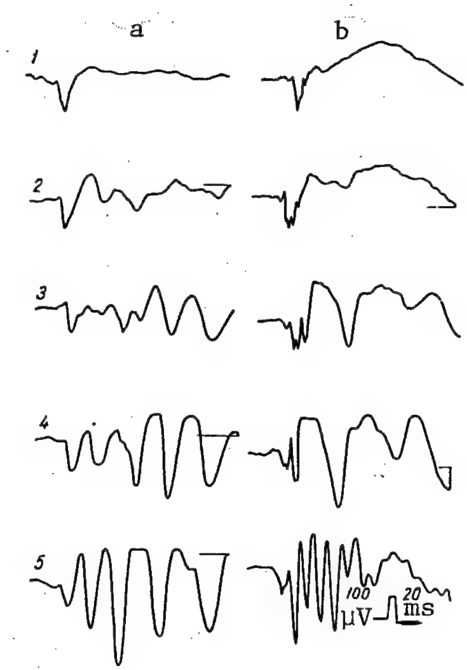

Figure 1.
Effect of SMF on EP of sensorimotor cortex (a) and hypothalamus (b). Calibration of amplification 100 μV and time 20 ms
1) before exposure
2,3,4,5) 0.1, 0.4, 0.8, 1.6 T, respectively

The demonstrated changes in brain EP corresponded in nature to the variants we previously described with induction at levels of up to 0.4 T [3, 7].

Figure 2 illustrates the average data on magnitude of effect as a function of intensity of magnetic field. As we see, with increase in magnetic induction

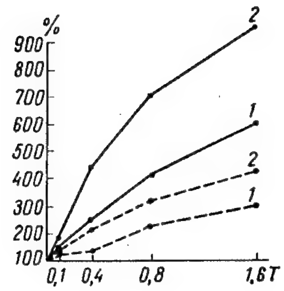

Figure 2.
Changes in brain EP amplitude as a function of magnetic field induction
X-axis, SMF induction (in T); y-axis, amplitude of EP (% of base value); dotted lines--primary responses, solid lines--maximum amplitude
1) cerebral cortex
2) hypothalamus

from 0.1 to 1.6 T, there is an increase in degree of increase in EP amplitude in both brain structures tested. The effect of the magnetic field was less marked for primary responses that high-voltage additional waves. We observed greater individual differences in animals' sensitivity to the magnetic field, as indicated by the significant fluctuations in magnitude of the magnetic effect on different rats. In spite of the distinct increase of effect with increase in intensity of the field, a 4-fold increase was required to obtain reliable differences in effects of different levels of induction. For example, the maximum amplitude of cortical response rose to 166.5±17.2% at 0.1 T, 257.9±37.8% at 0.4 T ($P<0.05$) and 598.2±150.4% at 1.6 T ($P<0.05$, as compared to 0.4 T). The same pattern could be demonstrated for hypothalamic EP.

While there was a similarity of reactions of both tested structures of the brain with regard to changes in amplitude of primary responses and high-voltage additional waves, there were appreciably more changes in amplitude of cortical potentials of the hypothalamus. This is indicative of the great sensitivity of the hypothalamus to magnetic fields, which we had also demonstrated previously using a narrower range of SMF induction [3]. The high sensitivity of the hypothalamus to magnetic fields was also reported by other authors [1, 2, 8-10].

Table 1. Effect of 1.6 T SMF on amplitude and time parameters of cortical EP

Time of examination	Latency period, ms	Number of phases	Peak-to-peak amplitude, μV	Duration, ms
Before exposure	10,6±1,1	2,3±0,2	184,9±20,2	70,9±7,1
In SMF:				
1-3 min	10,6±1,8	8,7±0,7*	719,3±111,9*	173,9±8,6*
15 min	10,7±1,0	8,5±0,7*	600,0±130,3*	197,4±5,7*
After exposure:				
1-3 min	10,5±1,4	2,2±0,2	161,8±9,6	87,6±12,7
10 min	11,3±1,9	2,2±0,2	145,5±12,2	82,1±12,5

* $P<0,05$.

Table 1 lists the changes in cortical EP with exposure to the more intensive SMF.

As can be seen in Table 1, while there were no changes in latency period, there was drastic increase in number of phases and overall duration of potential, significant increase in amplitude of the response, measured from peak to peak, in the part of the potential with highest voltage. These changes appeared almost immediately after the start of exposure, persisted at the same level for 15 min of exposure and disappeared rapidly after termination thereof. Thus, there was significant intensification of changes in size and shape of brain EP, which appeared at lower levels of induction, with exposure to SMF with 1.6 T; this was not associated with qualitative changes in the magnetic effect.

Table 2. Changes in amplitude of EP of the brain (% of base value) in SMF differing in characteristics

Brain structure	Induction, T	SP-15A electromagnet		SP-57A electromagnet	
		n	effect	n	effect
Cerebral cortex	0.1	26	140	30	166
	0.4	26	280	30	260
Hypothalamus	0.1	12	188	26	192
	0.4	12	360	26	371

A comparison of the data obtained previously to the results of this study (Table 2) shows that, with the same level of induction, the effect of increasing amplitude of brain EP is the same for magnetic fields that differ in the presence of a pulsating component.

It is known that variable magnetic fields have greater biological effectiveness than SMF. It was previously demonstrated that a weakly pulsating magnetic field generated in an SP-15A electromagnet has a stronger effect on static work capacity and behavior of rats in an "open field," than the strictly static field of the SP-57A electromagnet [11]. Evidently, pulsation is a biologically significant feature of the magnetic field to integral functions of the central nervous system. For this reason, it could have been assumed that the presence of a pulsating component could play an appreciable part in changing bioelectric reactions of the brain observed in magnetic fields. However, the identical nature of the effect and dose function in magnetic fields with the parameters we used shows that the biological effectiveness of these fields is determined primarily by magnitude of induction with regard to bioelectric processes in the brain.

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UDC: 612.419.014.2+612.112.94].014.482

CYTOGENETIC EFFECTS OF HIGH-ENERGY CHARGED PARTICLES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 5 May 81) pp 64-67

[Article by R. D. Govorun, S. V. Vorozhtsova and V. N. Gerasimenko]

[English abstract from source] The cytogenetic effects of irradiation were investigated in the bone marrow and corneal epithelium of mice, human white blood cells, and Stamm V79-4 cells of Chinese hamsters exposed to protons with E = 9.2 GeV, deutons and helium ions with E = 4.6 GeV/nucleon. It was demonstrated that with an increase in the irradiation dose the number of aberrant cells and chromosome aberrations grew. A high yield of exchange type aberrations was found. The proliferative activity of cells of bone marrow decreased and its depletion occurred. The RBE coefficients of high-energy particles varied from 1.3 to 2.7 in relation to the cell type and parameters measured.

[Text] We simulated the effects of galactic cosmic radiation (GCR) nuclei on the ground, using an accelerator, exposing animals, mammalian and human cells to charged particles of relativistic energy, comparable to the energy of heavy nuclei in space. We studied cytogenetic effects, which are the most adequate reflection of the immediate reaction of actively proliferating cells and tissues to radiation.

Methods

We used 250 male F-1 line mice weighing 20-22 g, as well as cultures of human peripheral blood lymphocytes and Chinese hamster strain V79-4 cells, in our experiments. The mice were irradiated in cylindrical cassettes made of plexiglas, placed in the synchrophasotron of the Unified Institute of Nuclear Research (Dubno), exposing them to protons with E = 9.2 GeV, deuterons and helium ions with E = 4.6 GeV/nucleon, in doses of 0.25 to 10.2 Gy at dose rates of 0.05, 0.008 and 0.006 Gy/s, respectively. Cell cultures were exposed to radiation in glass vials, in doses of 0.25 to 5.0 Gy. We used ^{60}Co and ^{137}Cr γ-quanta at dose rates of 0.061 and 0.075 Gy/s, respectively, to compare the findings to effects of a standard type of radiation.

The animals were decapitated 1 day after irradiation. The eyes were enucleated, fixed in Bouin solution and we prepared total corneal preparations, which were stained by the method of Caracci. We extracted bone marrow from cleaned femoral bone, resuspended it in hypotonic sodium citrate solution and prepared smears on slides, which were fixed in methanol, hydrolyzed with 5 N HCl at room temperature and stained with azure-eosin by the method of Romanovsky. Radiation damage to bone marrow cells and corneal epithelium of mice was assessed on the basis of impairment of proliferative activity and processes of cell division. The value of the mitotic index and amount of cells with chromosome aberrations in the form of bridges and fragments, which was determined by the anaphase method, served as criteria. In addition, we assessed depletion of bone marrow cellular elements according to karyocyte content of the whole femur of mice [1].

Preparations of lymphocytes from human peripheral blood were processed by the conventional method [2, 3]. Transferable Chinese hamster cells were cultivated in Eagle's medium with addition of calf blood serum (15%). Metaphase plate preparations were made by the conventional method. We assessed the deleterious effect of radiation according to quantity of aberrant cells and incidence thereof, as well as of different types of chromosomal aberrations.

Results and Discussion

The obtained results revealed that protons, deuterons, helium ions and γ-quanta elicited profound damage to the genetic system of cells, manifested by impairment of their proliferative activity and appearance of cells with various types of chromosome aberrations. In addition, there was depletion of bone marrow, with regatd to cellular elements. The severity of disturbances was related to type and dosage of radiation, as well as type of tissues and cells submitted to irradiation.

The nature of changes observed in mouse bone marrow was analogous to those demonstrated previously when animals were exposed to protons with energy of 50 to 645 MeV [4]. Depression of mitotic activity of cells, the severity of which increased with increase in dosage, was manifested for a long time. The mitotic index of mouse bone marrow cells did not exceed 20-30% of the control level, even 1 day after exposure to protons and helium ions of relativistic energy in doses of 5-10 Gy. At the same time, we observed more marked depression of mitotic activity of cells, as compared to the effects of γ-quanta.

The studies also revealed that cellular elements were depleted in mouse bone marrow. Figure 1 shows that, already 1 day after irradiation, there was a drastic reduction in overall quantity of karyocytes in bone marrow with increase in radiation dose. We failed to demonstrate appreciable differences between the effects of protons, deuterons and helium ions. Subsequently, on the 3d day after delivery of a wide range of doses (over 3 Gy) bone marrow became depleted, to the extent of virtually complete aplasia, when there remained about 4% cells in bone marrow, as compared to level in intact animals. We see that depletion of bone marrow after exposure to charged particles with relativistic energy occurred at a faster pace than under the influence of γ-quanta.

Evaluation of RBE coefficients using the criterion of 50% reduction in number of karyocytes in mouse bone marrow demonstrated that the time of examination was relevant. They constituted 2.7±0.9, 2.0±0.6 and 2.7±0.9 1 day after exposure to protons, deuterons and helium ions of relativistic energy, respectively, and 1.5±0.3 after 3 days (for protons and deuterons).

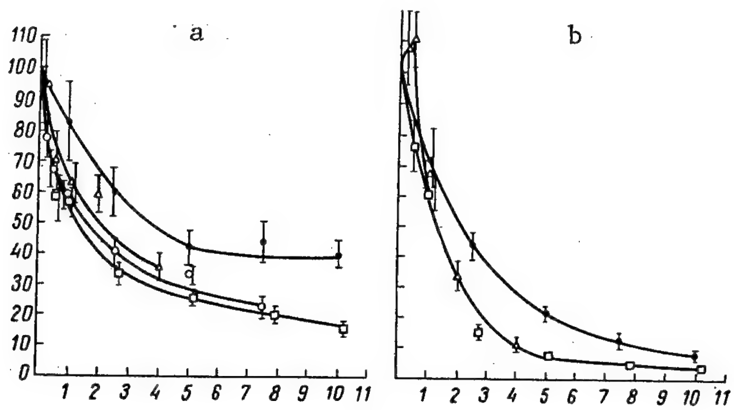

Figure 1. Karyocyte content of mouse bone marrow as a function of dosage 1 (a) and 3 (b) days after exposure to protons with E = 9.2 GeV (□), deuterons (Δ) and helium ions (o) with E = 4.6 GeV/nucleon and ^{60}Co (●) γ-quanta.

X-axis, radiation dose (Gy); y-axis, karyocyte content (% of control).

RBE coefficients of ions with relativistic energies

Biological effect	Biological object	Helium ions, 4.6 GeV/nucleon	Protons, 9.2 GeV	Deuterons, 4.6 GeV/nucleon
Increased number of aberrant cells	Mouse corneal epithel.	2,7±0,3	1,9±0,2	—
	Mouse bone marrow	2,0±0,5	2,6±0,3	2,0±0,5
	Human lymphocytes	1,6±0,2	1,4±0,2	—
	Chinese hamster cells	1,3±0,1	—	—
Increased chromosome aberrations	Human lymphocytes	1,6±0,2	1,6±0,2	—
	Chinese hamster cells	1,2±0,1	—	—
Reduced proliferative activity	Mouse bone marrow	1,6±1,1	3,0±1,3	—
Karyocyte content	Mouse bone marrow	2,7±0,9	2,7±0,9	2,0±0,6

During the period of resumption of mitotic activity, we found a drastic increase in number of cells with various chromosome aberrations with increase in radiation dosage (Figure 2). The dose-effect curves obtained for bone marrow cells and corneal epithelium of mice, human peripheral blood lymphocytes and Chinese hamster cells presented a linear initial segment up to a dose level of 1-2.5 Gy. With further increase in dose, we observed a change in nature of dose curves

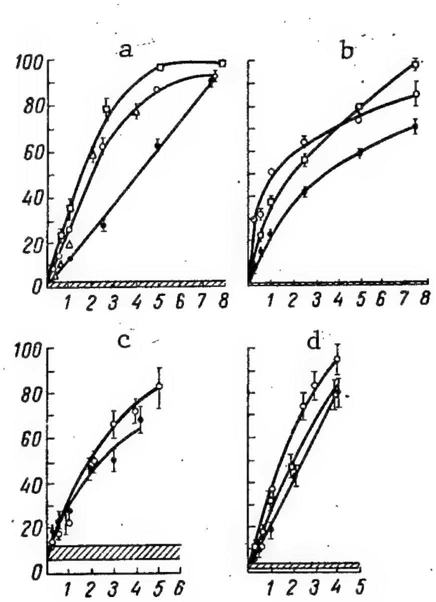

Figure 2.
Quantity of aberrant cells in bone marrow (a) and corneal epithelium (b) of mice, Chinese hamster cells (c) and human peripheral blood lymphocytes (d) as a function of dosage. X-axis, radiation dose (Gy); y-axis, aberrant cells (%). Symbols are the same as in Figure 1

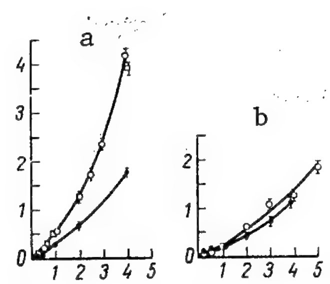

Figure 3.
Total number of chromosome aberrations in human blood lymphocytes (a) and Chinese hamster cells (b) as a function of dosage. X-axis, radiation dose (Gy); y-axis, aberrations per cell. Symbols are the same as in Figure 3

with formation of a "plateau" on levels corresponding to different types of cells (~80-95%). As compared to γ-quanta, we also observed that accelerated charged particles had higher effectiveness. RBE coefficients calculated from doses leading to formation of 50% aberrant cells in the tested cell populations changed in the range of 1.3-2.7, regardless of the type of charged particles.

In addition, we found an increase in quantity of chromosomal aberrations with increase in radiation dosage (Figure 3), and dose functions were exponential. As compared to the effects of γ-quanta, cells exposed to heavy charged particles developed more chromosome aberrations, particularly in the case of high doses. The latter was more distinct in the case of exposure of human peripheral blood lymphocytes.

In our opinion, the high yield of exchange type aberrations (dicentrics, rings, chromatic exchanges, bridges) was a distinctive feature in the effects of the tested particles with relativistic energy. The quantity of formed dicentrics and rings in human lymphocytes and Chinese hamster cells exposed to protons and helium ions was 1.5-2 times greater than the quantity of paired acentric fragments. The quantity of aberrant cells with bridges in mouse corneal epithelium was 3-10 times greater than cells with fragments, and the highest amounts were obtained with radiation doses of up to 2.5 Gy.

Comparative analysis of the biological effects of accelerated particles with relativistic energy and γ-quanta enabled us to demonstrate the greater effectiveness of ions when assessed by all of the tested parameters. The coefficients of RBE of protons, deuterons and helium ions of relativistic energy (see Table), which were calculated by different tests, changed in accordance with the type of cells examined, mainly in the range of 1.3-2.7. We can mention that the

lower RBE coefficients were obtained in the case of in vitro irradiation of the cells. These values are close to the RBE coefficients of high-energy helium ions, calculated by a number of authors, as compared to the effects of γ-quanta or x-rays, as assessed by different parameters: survival of neoplastic and normal mouse cells [5, 6], survival and developmental anomalies of rat embryos [7], early skin reactions in Syrian hamsters [8]. In these cases, the RBE coefficients were in the range of 1.2-2.0.

At the present time, the question of the causes of the greater deleterious effects of the tested particles with relativistic energy, as compared to the effects of γ-quanta, remains open. We believe that it was attributable to the contribution of secondary radiation (including high-density ionization), which appears as charged particles pass through cells as a result of nuclear interaction, the probability of which increases with such high energy of accelerated particles.

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UDC: 629.78:612.6.052.014.482.5

CYTOGENETIC EFFECTS OF HEAVY CHARGED PARTICLES OF GALACTIC COSMIC RADIATION IN EXPERIMENTS ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 5 May 81) pp 67-71

[Article by L. V. Nevzgodina and Ye. N. Maksimova]

[English abstract from source] The experiment was carried out on lettuce (Lactuca sativa) seeds flown in a biocontainer equipped with plastic detectors to record heavy charged particles (HCP). The purpose of the experiment was to determine the yield of aberrant cells as a result of irradiation, and to identify this effect as a function of HCP topography in the seed. The cytogenetic examination of flight seedlings revealed a significant difference between the seeds which were hit with HCP and those that remained intact. This indicates a significant contribution of the heavy component of galactic cosmic radiation into the radiobiological effect. The relationship between the radiobiological effect and the HCP topography in the seed was established: zones of the root and stem meristem proved to be the most sensitive targets.

[Text] Studies conducted aboard various Soviet and American flight vehicles revealed impairment of viability and egg development processes in Artemia salina [2], as well as some changes in cell structures and chlorophyll mutations in seeds of higher plants [1, 3].

During flight experiments with Lactuca sativa lettuce seeds, cells appeared that had several, rather than one, aberrations with absence thereof in control variants [4, 5].

It is important to mention that similar effects had been observed when biological systems were exposed to protons and γ-rays, but in doses of several krad.

Consequently, the effects observed in the flight experiments cannot be attributed to protons, which make up 85% of the flux of cosmic particles. It can be assumed that they were due to the effects of highly ionizing cosmic radiation, in particular, isolated heavy charged particles (HCP). Estimates have shown that when HCP traverse biological tissue, in a region with a radius of

20-200 Å of the track energy may be released that is equivalent to a dose of several units to hundreds of kilorad. Since the release of heavy particle energy is strictly localized, the observed effects could be attributed to damage to different sensitive structures of cells. In order to obtain such data, it is the most expedient to use biological systems combined with cosmic radiation HCP detectors in units of the "Bioblock" [biostack] type.

Our objective here was to obtain statistically reliable data on the quantity of chromosome aberrations as a function of HCP hits and topography of their trajectory through biological systems.

Methods

We conducted this study with Lactuca sativa, large-headed ("elite") lettuce seeds. Before beginning the flight experiment, the seeds were attached to a cellulose nitrate plate by means of polyvinyl alcohol. We used two containers in the Bioblock-4 experiment: an internal one, BB-1M (10×8×9 cm), similar to the one previously used in Bioblock-1,2 experiments, and an external one, 4 cm in diameter and 1.4 cm tall. In addition, we used identical containers for the transport and laboratory control.

The biostack of the internal container consisted of 15 monolayers of seeds alternating with plastic detectors (KNTs and Kodak) intended for recording HCP tracks (Figure 1). The external biostack, analogous to the internal one, consisted also of plates with lettuce seeds and physical plastic detectors.

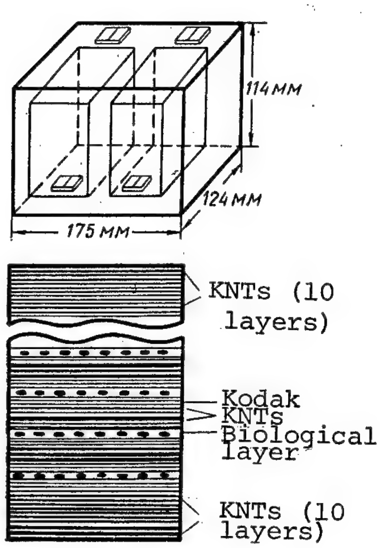

Figure 1.
Diagram of inside biostack of BB-1M container (top--general view; bottom--section). Mean dosage in biostack--0.32 rad

We used thermoluminescent dosimeters (TLD) to record the overall dose. The mean dosage for the entire flight constituted 0.3 rad in the inner container and 0.4 to 0.6 rad in the outer one, depending on how the biological objects were shielded.

After completion of the flight and return to earth, the containers were disassembled. The detectors were treated with alkali to demonstrate HCP tracks. For examination, the detectors were assembled with the same coordinate system as during exposure. The biological objects, through which heavy particles had passed, were recorded when examined together in a layer of biological objects and by detectors adjacent to it. Use of a stereomicroscope enabled us to view all layers at the same time. The coordinates of

the trajectory of particles through the biological object were determined with accuracy to 10-15 μm. The cellulose nitrate detectors recorded HCP with charge (Z) of 10 to 24, linear energy transfer of 1740 to 18,800 MeV•cm^2/g and particle energy (E) of 5 to 140 MeV/nucleon.

We used the following variants in the experiment: laboratory and transport control, flight (seeds that were hit and not hit by HCP, from inner and outer biostacks).

One week after the satellite landed, all variants of seeds were soacked in tap water and sprouted. Seedlings were fixed in the first mitosis (seedling length not exceeding 4 mm) in a mixture of acet-alcohol (1:3). The effect was assessed on the basis of yield of cells with chromosomal aberrations at the anaphase-telophase stage, counting all types of aberrations on temporary acetorcein preparations.

To determine the exact location of HCP hits in the object, we made histological sections of the seed with indication of the different sensitive structures (Figure 2). After scanning, all of the HCP hits in the seed were distributed into the main groups. To assess the severity of damage to the cell nucleus, in particular, chromosome aberrations, the region of the root meristem, which occupies 3% of the volume of the entire seed, is of interest from the standpoint of target.

Results and Discussion

We found that only 5% (6.0% from the outer container and 4.8% from the inner one) of all seeds exposed in the biostack and examined were hit by HCP.

Examination of the topography of the trajectory of HCP in each seed separately (data referable to two containers), we found that the largest number of HCP hits was referable to the cotyledon (41.8% of all seeds touched). There was an insignificant number of HCP hits in the root and stem meristems (4.8 and 3%, respectively). In addition to seeds hit by 1 heavy particle, we observed 12 instances where a seed was hit by 2 HCP (3% of all seeds hit by HCP).

As can be seen in Table 1, the data referable to control variants did not differ with regard to the criterion of aberrant cells.

Cytogenetic analysis of seeds from the inner biocontainer failed to demonstrate differences between flight and ground-based control samples. We found an increase in number of aberrant cells in the outer biostack, double the number in the control.

A comparison of the results in the flight variants of seeds, both hit and not hit by HCP, revealed reliable differences in percentage of aberrant cells, in both the outer container (4.30 and 2.75%, respectively) and inner one (2.12 and 0.96%). HCP whose tracks were demonstrated in the immediate vicinity of seeds did not affect the yield of aberrant cells (0.69, versus 0.96% in seeds not touched by HCP).

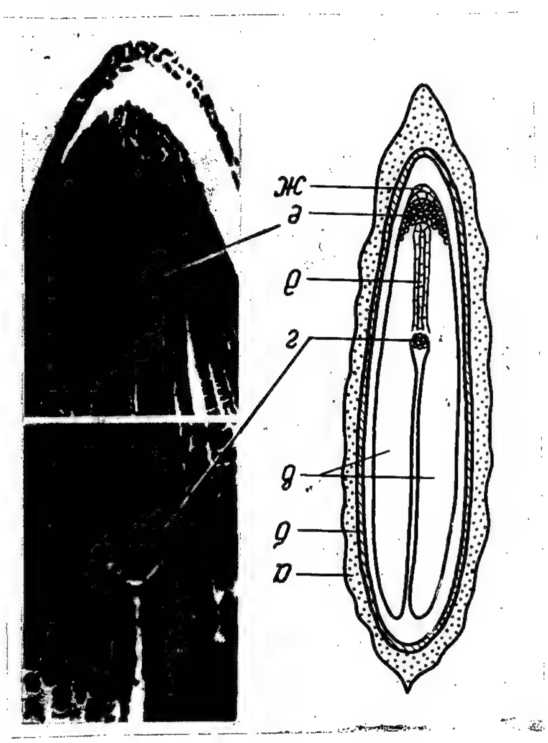

Figure 2.
Longitudinal histological section of lettuce seed

- *а*) pod
- *б*) ovule
- *в*) cotyledon
- *г*) stem apical system
- *д*) hypocotyl
- *е*) root apical system
- *ж*) root cap

Figure 3.
Lettuce seedlings on 12th day of development with HCP hit in hypocotyl (left) and without hit (right)

We also observed differences between variants in yield of multiple aberrations. The latter were demonstrated in seed cells of inner container which were hit by HCP, and in seeds stored loosely. In the outer container, multiple aberrations were noted in both hit and unhit seeds, but mostly in those hit by HCP. Accordingly, there was the same correlation between number of aberrations per aberrant cell. It should also be noted that all of the seeds hit by HCP were characterized by more marked delay in sprouting.

Cytogenetic analysis of each seed separately revealed some correlation between yield of aberrant cells and topography of HCP hits. The data listed in Table 2

indicate that the region of the root meristem and area adjacent to it are the most sensitive targets. In this case, the percentage of aberrant cells was high, particularly when specimens were fixed after 100 h. A high level of aberrant cells was also found in seeds hit by two HCP. When there was a hit in the seed hypocotyl, we also observed an increase in incidence of aberrant cells, as well as changes in shape formation of seedlings in the region of the hypocotyl where a particle track was found (Figure 3).

Table 1. Yield of aberrant cells in seedlings from seeds exposed in outer and inner containers aboard Cosmos-1129 biosatellite

Variant	Aberrant cells % (M±m)	Multiple aberrations,% (M±m)	Aberrations/ aberrant cell
Laboratory control:			
loose seeds	1,20±0,10	0,03±0,02	1,02
pasted	1,28±0,20	0,02±0,02	1,02
Transport control:			
pasted	1,23±0,20	—	1,00
Flight, inner container			
loose seeds	1,84±0,23	0,09±0,05	1,06
seeds not hit by HCP	0,96±0,10	—	1,00
seeds hit by HCP	2,12±0,10	0,12±0,03	1,06
HCP tracks next to seeds	0,96±0,20	—	1,00
Flight, outer container			
seeds not hit by HCP	2,75±0,20	0,19±0,06	1,07
seeds hit by HCP	4,30±0,50	0,69±0,20	1,18

Table 2. Yield of aberrant cells as a function of location of HCP hit in seed (inner container), M±m

Yield of aberrant cells	No hits	Root meristem (RM)	Stem meristem (SM)	Region next to RM	Region next to SM	Hypocotyl	Cotyledon	Pod	Two hits
Fixation before 100 h	0,92±0,11	2,25±0,99	0,80±0,80	1,53±1,07	0,92±0,32	2,50±1,40	1,13±0,27	1,90±0,40	2,46±0,64
Fixation after 100 h	2,12±0,40	7,30±2,80	2,00±0,56	2,84±0,64	2,16±0,20	1,32±0,65	2,25±0,28	3,36±0,60	2,96±0,68

Our results concerning incidence of aberrant cells in seedlings from seeds hit by HCP when flown in space are indicative of the appreciable contribution of the heavy component of galactic cosmic radiation to the radiobiological effect. This is very consistent with the data from the Biostack-3 and Bioblock-2 experiments [2, 5, 6]. However, other studies showed that there was no difference between biological objects that were or were not hit by HCP [7]. In studies where different groups of seeds with HCP hits were not taken into consideration, there was demonstration of a wide scatter of fluctuation of the effects observed [8]. The dissimilarity of the obtained results can apparently be attributed to

the fact that the effects were assessed without considering the topography of the particle in the object in relation to the target (meristem of root, of stem). This is confirmed by data obtained with barley; a high incidence of mutations, which persisted in subsequent generations, was demonstrated when the specimen was hit by HCP in the center. The same incidence of mutations was observed with exposure to x-radiation in doses that elicited depression of sprouting in 95% of the cases [8]. A high percentage of multiple aberrations was observed in the Bioblock-2 experiment, with hits in the root meristem [4]. Moreover, when there were central HCP hits in biological objects, a seedling with two rootlets [2] and chlorophyll mutations [3] were demonstrated, which had not been encountered previously either in other flight experiments or in experiments using heavy particle accelerators.

We should note the following: the actual doses recorded in all of the above-mentioned flight experiments did not exceed 1 rad, which did not correspond to the effects obtained when specimens were flown in space.

Thus, as a result of studies aboard the Cosmos-1129 biosatellite with use of physical detectors, we succeeded in assessing the contribution of individual TCP to the overall effect and dependence of effects on localization of HCP in the seed. The concept of dosage, generally used in radiobiology for quantitative interpretation of biological effects of HCP, is apparently unsuitable. The fact that a particle makes a hit, with quantitative consideration of transferred energy in assessing the "yield" of biological reaction per particle, could serve as a more adequate criterion.

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METHODS

UDC: 612.886.014.47:531.15

MEASUREMENT OF VESTIBULAR ASYMMETRY IN ROTATION TESTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 19 Oct 81) pp 71-72

[Article by T. A. Nalimova, A. B. Savinkov and R. V. Kofanov]

[Text] Asymmetry of direction of nystagmus may be one of the objective signs of preclinical vestibular dysfunction. Directional asymmetry, or so-called directional dominance of nystagmus, is usually demonstrated by means of a bithermal test, i.e., a set consisting of four caloric tests (hot and cold for each ear). The coefficient of directional dominance is calculated as the difference between intensity of right and left nystagmus, expressing this difference as percentage of total intensities of all four reactions:

$$\mathrm{DD} = \frac{(a + d) - (b + c)}{a + b + c + d} \times 100(\%) \qquad (1)$$

where a is the quantitative characteristic of heat nystagmus obtained upon stimulation of the right ear, b is the same with stimulation of the left ear, c and d are characteristics obtained with cold stimulation for the right and left ear, respectively. The sign of DD is indicative of direction of dominant nystagmus: plus refers to dominance of reactions to the right and minus to the left.

Each of the four types of nystagmus in the bithermal test is the result of a change in afferent flux from one of the labyrinths to the centers: there is increased afferentation with heat and diminished with cold.

The intensity of nystagmus is proportional to the degree of change in one of the afferent fluxes, since these changes determine the difference in activity of vestibular nuclei on the right and left. Since afferent flows change simultaneously in both vestibular nerves in the rotation test (intensification on one side is associated with decline on the other), the intensity of nystagmus elicited by angular acceleration can be interpreted, by analogy to the sum of intensities of caloric reactions in the same direction. For example, with a sudden stop after rotation in the horizontal place counterclockwise, the intensity of nystagmus is due to cupuloendolymphatic changes in the right (ampullopetal shift) and left (ampullofugal shift) lateral canals. Each of these

shifts determines part of the intensity of the reaction, and the former can be arbitrarily viewed as an analogue of the heat test on the right and the second, as that of the cold test on the left. Consequently, in this example, the intensity of postrotatory nystagmus to the right can be considered by analogy to the sum of intensities of two caloric nystagmuses ($a + d$).

Such analogy enables us to use rotatory tests for determination of directional dominance of nystagmus, and the formula acquires the following appearance:

$$DD = \frac{A - B}{A + B} \times 100(\%) \tag{2}$$

where A and B are intensity of right postrotatory and left nystagmus, respectively.

Methods

In order to detect transient vestibular dysfunctions, we examined a group of workers (30 people) who were regularly exposed to vibration and noise at work.

As a control group, we had 15 essentially healthy subjects referable to engineering and technical personnel at the enterprise. The groups were similar in age composition. We used rotation to the right and left in a Barany chair (5 turns per 10 s) with sudden stopping. The immediate result of testing each subject consisted of four electronystagmograms (ENG) recorded on 1 day (2 ENG before the work shift and 2 after ending work). We calculated on each ENG duration of reaction, as well as mean frequency, mean amplitude and mean speed of the slow component (SSC) per 10-s segment at the phase of culmination of the reaction.

Results and Discussion

A comparison of the above-mentioned arithmetic means of nystagmometric characteristics failed to demonstrate differences between parameters of the tested groups. We also failed to demonstrate a difference in these characteristics between ENG recorded before and after work.

This finding indicates that there were no gross disturbances in the vestibular system.

We used a procedure of processing nystagmometric data analogous to calculation of coefficient of directional dominance of nystagmus (formula 2) to demonstrate transient functional disturbances, the presence of which could be suspected because of complaints of headache, fatigability and transient vertigo, which usually developed toward the end of the work shift.

Similar results were obtained when we averaged individual asymmetries with consideration of the sign in both groups of subjects for all nystagmometric parameters: mean DD did not differ reliably from zero. The findings were different when we made the comparison with averaging of DD modulus, i.e.,

when we made the assessment according to absolute value without considering the sign [plus or minus]. In particular, we found that the mean moduli of DD for frequency and SSC for workers were double the values for the control group of subjects. This was the first objective confirmation of the assumption that functional changes were present.

A comparison of evening and morning results, according to moduli of DD averaged for each group, failed to demonstrate reliable differences in any of the characteristics, i.e., signs indicative of changes in the vestibular system occurring in the course of the work were not demonstrable, as before. Because of this, we altered our tactics for assessing the results: we evaluated individual DD changes occurring in the course of the data.

We found that these changes could reach significant dimensions and that this was often associated with a change in DD sign. In particular, there was a change in sign of DD in 15 subjects, when evaluation was made according to frequency. To assess this type of changes in DD, we calculated the difference between evening and morning values of DD. For example, in one subject, the DD constituted +2% in the evening test and +19% in the morning; consequently there was a 17% shift. In another case, DD constituted +52% in the evening and -26% in the morning, i.e., there was a 78% shift. The arithmetic mean of individual differences in shifts calculated in a similar manner constituted 20±0.06% for frequency ($X \pm m$) and 31±0.06% for SSC. The mean shift of DD for duration constituted 18±0.06%. No reliable changes were demonstrated in the control group of subjects.

The results of these studies revealed that it is not so much the absolute values of nystagmometric characteristics as degree of their asymmetry and, what is particularly important, significant variability of asymmetry, which can be detected by means of analysis of dynamics of the DD coefficient, that are of interest for detection of functional disturbances of the vestibular system (particularly with the preclinical form of vibration sickness).

UDC: 612.172.4-06+616.12-073.97-072.7

COMPARATIVE EVALUATION OF INFORMATIVENESS OF THREE CORRECTED ORTHOGONAL LEADS AND TWELVE CONVENTIONAL EKG LEADS IN CONDUCTING FUNCTIONAL TESTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 10 Jul 81) pp 72-75

[Article by V. D. Turbasov and Z. A. Golubchikova]

[Text] Many works have been published that deal with comparison of informativeness of 3 corrected orthogonal leads (3 COL) and the 12 conventional EKG leads, including use of the method of reconstruction ("synthesis") of leads [1-4]. Yet there are no data pertaining to comparative evaluation of these systems of leads when conducting functional tests, in particular, such widely used tests in space medicine as postural and LBNP (lower body negative pressure).

Methods

We conducted this study on 6 healthy men 25 to 35 years of age. Reconstruction ("synthesis") of conventional leads from 3 COL (Frank system) [5] was done on a Resolver machine. The EKG was recorded successively in the 3 COL and conventional ("direct" and "synthesized") leads as follows: During postural tests in horizontal position (0°) and at angles of -15°, -30°, +30°, +60°, +75°; during LBNP--in the background, at -35 mm Hg rarefaction, -40 and -50 mm Hg.

For comparative evaluation we used the parameters of vector and quantitative analysis: $\overline{M}QRS$, $\overline{M}T$, $\overline{M}G$, $\sphericalangle QRS$, $\sphericalangle T$, $\sphericalangle G$, $\sphericalangle QRS - \sphericalangle T$, $\sphericalangle QRS - \sphericalangle G$,

$$\frac{R_x + S_y + S_z}{S_x + R_y + R_z}\left(\frac{R_{V_6} + S_{aVF} + S_{V_2}}{S_{V_6} + R_{aVF} + R_{V_2}}\right)$$

The data were processed by means of two-factor variance analysis and the S method of multiple comparison on a computer. Factor A was the system of leads and factor B the intensity of test element.

Results and Discussion

The dynamics of compared EKG parameters in COL, "synthesized" and "direct" leads presented the same direction and were related to the factor used (Tables 1-3).

Table 1. Results of two-factor variance analysis

Parameter	Source of variation (factor)	Functional test: postural, S^2	postural, F_{exp}	LBNP, S^2	LBNP, F_{exp}
$\bar{M}QRS$, μV·s	A	452,13	6,07*	210,31	2,90
	B	38,83	0,52	15,07	0,21
$\bar{M}T$, μV·s	A	1563,88	6,20*	150,66	0,73
	B	3099,04	12,29*	1693,56	8,21*
$\bar{M}G$, μV·s	A	4260,01	18,86*	681,95	3,89*
	B	3971,11	17,58*	1933,14	11,08*
$\frac{Rx + Sy + Sz}{Sx + Ry + Rz}$	A	0,1678	1,35	0,3935	2,48
	B	0,2244	1,80	0,2447	1,54
∢ T	A	967,62	2,77	1064,[illegible]4	2,69
	B	461,36	1,32	164,04	0,41
∢ G	A	1558,65	4,15*	1010,44	2,08
	B	243,44	0,65	206,14	0,43
∢ QRS	A	3205,25	5,18*	810,15	0,93
	B	586,11	0,95	33,82	0,04
∢ QRS — ∢ T	A	3298,74	7,18*	1215,86	4,40*
	B	1500,81	3,27*	24,89	0,09
∢ QRS — ∢ G	A	1025,75	5,88*	508,65	6,17*
	B	88,57	0,51	37,71	0,46

Note: In postural tests--factor A, df = 2, $F_{0.05}$ = 3.10; factor B, df = 5, $F_{0.05}$ = 2.32; with LBNP--factor A, df = 2, $F_{0.05}$=3.15; factor B, df = 3, $F_{0.05}$ = 2.70. Asterisk shows statistically significant ($P<0.05$) influence of factor.

Table 2. Dynamics of EKG parameters during postural tests

Parameter	Leads	Backgr. (0°) $\bar{y}$	Backgr. (0°) S^2	−30° $\bar{y}$	−30° S^2	+75° $\bar{y}$	+75° S^2
$\bar{M}QRS$, μV·s	COL	31,46	44,78	31,92	54,75	28,91	105,15
	Synthesis	25,97	26,72	26,85	65,45	24,99	113,46
	Direct	23,31	45,07	21,48	42,07	23,65	189,41
$\bar{M}T$, μV·s	COL	65,65	286,23	63,36	266,56	32,13	210,58
	Synthesis	50,66	296,58	52,81	404,88	28,25	202,11
	Direct	49,86	230,91	51,65	183,34	25,46	144,26
$\bar{M}G$, μV·s	COL	95,00	297,43	93,64	312,67	58,11	191,34
	Synthesis	74,63	240,06	77,28	473,04	48,45	120,15
	Direct	70,15	192, 2	70,22	130,27	44,90	30,37
$\frac{Rx + Sy + Sz}{Sx + Ry + Rz}$	COL	1,43	0,1485	1, 7	0,1126	1,22	0,0625
	Synthesis	1,60	0,2629	1,61	0,2917	1,34	0,0858
	Direct	1,52	0,1118	1,61	0,1177	1,37	0,0453
∢ QRS, degrees	COL	[illegible]1,76	301,27	42,08	332,85	52,68	471,77
	Synthesis	60,05	683,83	60,67	705,11	71,34	427,65
	Direct	55,85	873,15	50,91	951,08	70,43	365,52
∢ T, degrees	COL	26,28	85,37	30,90	142,93	19,35	97,48
	Synthesis	36,96	458,94	43,18	348,35	23,45	530,29
	Direct	27,56	55 ,88	24,31	567,77	17,35	467,02
∢ G, degrees	COL	31,61	133,29	34,85	175,49	37,75	186,02
	Synthesis	46,21	491,74	50,00	405,98	50,83	423,98
	Direct	38,01	573,58	32,83	580,77	47,78	452,39
∢ QRS—∢ T, degrees	COL	17,88	159,83	14,41	88,54	33,33	624,67
	Synthesis	24,68	275,84	21,31	183,85	49,63	851,83
	Direct	31,01	515,37	32,13	485,83	56,88	759,61
∢ QRS—∢ G, degrees	COL	11,38	72,81	9,76	49,50	14,95	164,66
	Synthesis	15,06	97,08	13,56	77,09	21,75	222,11
	Direct	19,96	231,09	21,98	313,13	25,51	317,96

Table 3. Dynamics of EKG parameters during LBNP

Parameter	Leads	Background $\bar{Y}$	Background S^2	−35 мм Hg $\bar{Y}$	−35 мм Hg S^2	−50 мм Hg $\bar{Y}$	−50 мм Hg S^2
$\bar{M}$QRS	COL	30,71	19,19	26,55	37,76	25,45	62,89
	Synthesis	22,22	30,45	23,11	93,54	22,46	83,11
	Direct	21,89	60,58	21,05	97,31	21,00	119,99
$\bar{M}$T	COL	52,88	228,53	33,60	227,89	28,04	138,71
μV·s	Synthesis	42,79	228,82	31,66	252,47	24,90	210,29
	Direct	46,43	160,63	31,96	201,61	23,47	142,24
$\bar{M}$G	COL	82,41	169,85	60,29	261,87	52,68	108,80
	Synthesis	63,44	198,96	54,26	153,64	46,34	205,39
	Direct	65,81	106,78	58,85	158,89	42,82	202,14
$\frac{R_x + S_y + S_z}{S_x + R_y + R_z}$	COL	1,34	0,1492	1,24	0,1536	1,18	0,1039
	Synthesis	1,66	0,2634	1,45	0,2117	1,40	0,3379
	Direct	1,66	0,0612	1,34	0,0834	1,37	0,0866
∢QRS	COL	49,60	445,24	50,80	400,52	54,25	298,37
	Synthesis	58,22	827,11	60,68	889,85	61,97	869,41
	Direct	50,21	921,52	48,11	1619,1	48,86	1617,4
∢T	COL	35,80	184,36	37,96	188,74	42,30	345,79
degrees	Synthesis	38,68	254,65	49,21	455,07	43,83	239,88
	Direct	26,90	389,38	29,38	602,74	36,20	545,72
∢G	COL	41,70	249,13	44,72	253,36	48,00	262,69
	Synthesis	47,83	353,36	56,13	621,37	55,14	480,52
	Direct	35,77	516,39	40,05	829,18	45,13	586,19
∢QRS — ∢T	COL	18,80	95,88	16,37	176,89	18,32	128,23
	Synthesis	23,70	372,38	14,73	172,58	22,53	161,39
	Direct	30,48	344,72	34,43	346,07	29,66	615,66
∢QRS — ∢G	COL	11,60	37,16	8,45	44,13	9,58	39,61
	Synthesis	13,55	79,19	7,12	35,96	10,15	35,47
	Direct	18,82	140,75	19,65	107,88	16,16	208,79

We observed a statistically significant (P<0.05) difference between some parameters with COL, on the one hand, and conventional (direct" and "synthesized") leads, on the other: the influence of factor A (see Table 1). At the same time, analogous parameters in the "direct" and "synthesized" leads differed insignificantly and without statistical significance (P>0.05). The difference in EKG parameters using COL and conventional leads was consistently attributable to the differences between these systems (electrodes placed in different locations, additional resistance in forming COL, etc.).

The intensity of the tests (factor B) had a statistically significant (P<0.05) effect only on some parameters (see Table 1). When the subjects were moved from horizontal to antiorthostatic (-15° and -30°) position, we failed to demonstrate appreciable changes in parameters of quantitative and vector analysis (see Table 2). Progressive change in some of them differed when the subjects changed to orthostatic position as the angle of inclination increased (see Table 2).

The most marked changes were observed in the following parameters: $\bar{M}$T and $\bar{M}$G diminished and were lower with all levels of orthostatic position than in horizontal and antiorthostatic positions (P<0.05); ∢QRS increased and in +75° position it was considerably greater, but without statistical significance (P>0.05), than in horizontal and antiorthostatic position; ∢QRS - ∢T increased

and in +75° position was greater, with statistical significance ($P<0.05$), than in horizontal and antiorthostatic position; parameter $\frac{Rx + Sy + Sz}{Sx + Ry + Rz}$ decreased, and this corresponded to the increase in ∢QRS (see Tables 1 and 2).

With LBNP, the direction of changes in parameters compared (with the exception of ∢QRS, ∢T and ∢QRS - ∢T) corresponded in general to the changes with the orthostatic test (see Table 3).

On the basis of the similarity of EKG parameters ($\overline{M}T$, $\overline{M}G$, ∢G) with LBNP and in the orthostatic tests, it can be assumed that factors unrelated to anatomical position of the heart are of predominant significance in the genesis of changes in the repolarization phase. Evidently, neuroregulatory changes and redistribution of blood exert the greatest influence. The changes in repolarization phase of the ventricular myocardium can be classified as being of type II [6], which is defined as "primary disturbances, in the presence of which the magnitude of the gradient changes, but not the direction." This type is observed more often in the presence of functional disturbances. In view of the good individual tolerance of the tests by our subjects and lack of objective signs of worsening of their hemodynamics, we interpreted the disturbances in repolarization phase as being functional, due to orthostatic changes and changes in distribution of blood.

Altered body position and LBNP imply that there is a change in position of internal organs, including the heart, shifting of the electrodes and redistribution of blood. As a result, there is a shift of the "electric center" of the heart, coordinate system of leads, with impairment of neurohumoral regulation of the cardiovascular system, which is manifested by EKG changes [6-10].

The similarity of dynamics of EKG parameters in the COL and conventional leads indicate that the shift of the "electric center" of the heart in relation to coordinate systems of corrected and conventional leads is the same. The resemblance of dynamics of EKG parameters in "direct" and "synthesized" leads indicates that the coordinate system of the latter does not change appreciably during functional tests, as compared to the coordinate system of "direct" EKG leads.

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UDC: 616.153.1-074-092.9:599.82

DIAGNOSTIC USE OF ENZYMATIC TEST IN EXPERIMENTS ON MONKEYS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 21 Sep 81) pp 75-81

[Article by G. S. Belkaniya and N. I. Lemondzhava]

[Text] At present there are numerous data on the high diagnostic value of measuring activity of creatine phosphokinase (CPK), aspartate aminotransferase (AST) and alalnine aminotransferase (ALT) in blood serum, in clinical practice [1-5]. It has been determined that these serum enzymes are sensitive indicators for early detection of myocardial infarction, and that they are also important in dynamic monitoring of patients and forecasting development of a disease [6-11]. The comparability of enzymatic activity of blood serum to pathomorphological findings makes it possible to define the enzymatic test as a promising method for intravital diagnosis of destructive processes that occur in the presence of various functional disturbances and pathological states [5]. For this reason the use of enzymodiagnostic methods is deemed a rather important clinical and experimental direction [12].

The extensive use of primates in biomedical experiments, including space investigations, is the reason why it is expedient to use enzymodiagnostic methods to assess the state of structures and functions of different organs and systems of these animals. However, the available information about activity of blood serum enzymes of primates is very sparse and represented by isolated studies dealing with special issues [13, 14].

We have analyzed here standardized data on serum activity of the three most widely used enzymes (CPK, AST, ALT) in clinical practice and direction of enzymatic changes in the presence of various functional and pathological states in monkeys, in order to elaborate enzymodiagnostic criteria.

Methods

Standardized data on serum activity of CPK, AST and ALT were obtained as a result of examining 461 healthy monkeys (370 Macaca rhesus and 91 sacred baboons [Papio hamadryas]) of both sexes and different ages. We also tested enzyme activity in blood serum with use of various situational factors (capturing, immobilizing animals, feeding conditions) of functional and pathological states.

Blood was taken for tests from the veins of the extremities, in fasting animals, in the mornings. Aminotransferase activity was measured by the standard technique of Paskhina and CPK according to Muller et al. The obtained results were submitted to processing by methods of parametric and nonparametric statistical analysis.

Results and Discussion

When using any diagnostic test, working out standardized data is quite important. For this reason, we made a biometric analysis, first of all, of standard range of fluctuation of serum activity of CPK, AST and ALT in the two species of primates used the most in experimentation.

We failed to demonstrate appreciable species-specific differences in serum enzyme activity of M. rhesus and baboons (Table 1). This enabled us to describe the variational distribution of enzyme activity without consideration of animal species. Figure 1 shows quite clearly that the curves of distribution AST and ALT activity approximate the curve of normal distribution while cumulative distribution of aminotransferase activity forms an S-shaped curve, which is also inherent in normal distribution. However, the distribution curve of CPK activity and cumulative distribution thereof are less close to the form of normal distribution. If we consider that in all of the tested standard conditions (sex, age, time of year, upkeep conditions) CPK activity fluctuated more than aminotransferase activity, the difference in nature of variational distribution of activity of these enzymes becomes understandable. Moreover, serum CPK activity changed more appreciably than that of aminotransferases in the presence of experimental situational factors (catching animals, immobilization, repeated presentation [of food?], tying them up, etc.). The combined effect of all these factors cancels out the normal variational distribution of CPK activity, which can apparently be demonstrated in a more standard sample, considering both

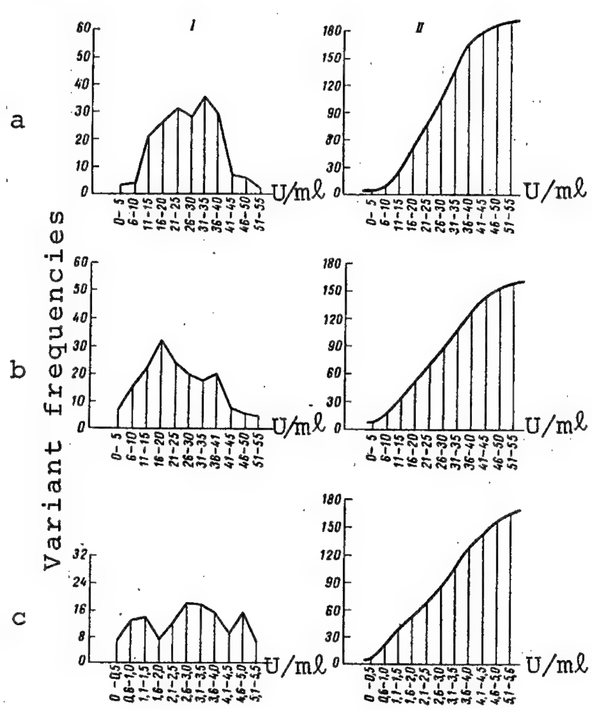

Figure 1.
Variation curve (I) and cumulative curve (II) of distribution of activity of AST (a), ALT (b) and CPK (c) in monkey's blood serum; y-axis: I) frequency of variants, II) cumulative frequencies

population characteristics and experimental conditions. Evidently, if all these conditions were adhered to, there would be greater correspondence of individual fluctuations of serum activity of aminotransferases also to the normal distribution, since age-related differences in activity of these enzymes were substantial, in spite of the fact that AST and ALT activity did not differ appreciably in males and females. This was reflected by the asymmetry of variation curves of distribution of serum AST and ALT activity.

Table 1. General standard data on serum CPK, AST and ALT activity of Macaca rhesus and Hamadryad baboon monkeys

Enzymes	Overall activity unit/mℓ	Sex		Main age groups			
		females [sic]	females [sic]	adoles-cents	tran-sient age	adults	old
		Macaca rhesus					
CPK	2,82±0,07 (0,075—5,25) 172	2,68±0,10 (0,075—5,20) 101	2,99±0,13 (0,075—5,25) 71	3,12±0,04 (0,70—5,00) 37	3,32±0,19 (0,625—5,20) 33	2,44±0,11 (0,075—5,25) 85	2,84±0,53 (0,25—5,25) 17
AST	27,32±0,67 (4,00—54,00) 194	26,16±0,96 (6,00—48,00) 81	28,16±0,92 (4,00—54,00) 113	26,48±1,30 (4,00—2 ,00) 45	27,00±1,92 (4,00—49,00) 32	28,53±0,82 (8,00—51,00) 107	21,50±3,57 (7,00—40,00) 10
ALT	22,35±0,72 (4,00—55,00) 172	21,34±1,20 (4,00—53,00) 73	23,10±1,02 (4,00—55,00) 99	15,54±1,27 (4,00—41,00) 39	24,07±2,19 (6,00—53,00) 29	28,54±1,01 (4,00—53,00) 94	22,80±2,70 (10,00—35,00) 10
Rittis coefficient	1,22	1,22	1,22	1,70	1,12	1,00	0,94
		Hamadryad baboons					
CPK	3,28±0,18 (0,30—5,70) 44	3,05±0,23 (0,30—5,70) 32	3,91±0,33 (2,00—5,60) 12	3,20±0,90 (0,30—5,40) 6	—	3,44±0,26 (0,30—5,70 28	2,88±0,43 (1,70—5,70) 10
AST	25,34±1,84 (4,00—48,00) 80	25,38±1,15 (4,00—48,00) 66	25,14±3,02 (7,00—44,00) 14	28,00±3,60 (4,00—43,00) 12	—	23,85±1,31 (4,00—44,00) 47	27,14±2,13 (12,00—48,00) 21
ALT	20,89±1,19 (5,00—52,00) 69	20,85±1,32 (5,00—52,00) 59	21,20±3,46 (6,00—38,00) 10	24,75±4,25 (5,00—51,00) 12	—	18,31±1,13 (6,00—38,00) 40	22,12±3,06 (8,00—52,00) 17
Rittis coefficient	1,21	1,22	1,18	1,13	—	1,30	1,23

Note: This table lists the following statistical parameters: $x \pm S_{\bar{x}}$; Δx--scatter of fluctuations (in parentheses) and *n*--number of animals.

The highest serum CPK activity in female Macaca was observed at the transient adolescent age (4.13±0.31 U [units]/mℓ), whereas in males the serum activity of this enzyme at the same age was lower (3.02±0.23 U/mℓ). Maximum blood serum AST activity in males and females (39.8±3.5 U/mℓ) was demonstrable at the age of 6-7 years, and that of ALT at the age of 5-8 years (39.8±3.5 U/mℓ). Considering the fact that the rate of synthesis and secretion of hormones, intensity of their metabolism in tissues and sensitivity of tissues to hormonal influences change with age [15, 16], the age-related changes in enzyme activity could be related, to some extent. to the state of hormonal regulation. The significance of the latter is also demonstrable in our analysis of age-related changes in enzyme activity at different stages of maturation. These changes

were more prominent in females and this could, to some extent, be related to the more cardinal alteration of their hormonal function, as compared to males. At the same time, analysis of CPK, AST and ALT activity in adult females revealed that there were insignificant fluctuations in activity of the tested enzymes at different phases of the menstrual cycle.

The highest seasonal level of CPK activity was demonstrable in the spring and summer (3.7±0.4 U/mℓ), as compared to winter (2.1±0.3 U/mℓ), whereas aminotransferase activity was lowest at this time (AST 22.5±1.5 U/mℓ, ALT 20.0±1.5 U/mℓ). Perhaps, the relative increase in serum AST (29.2±1.5 U/mℓ) and ALT activity (39.1±1.3 U/mℓ) in the winter months is a reflection of elevation of basal metabolism at this time of the year. Thus, the studies of A. D. Slonim [17] demonstrated a distinct increase in exchange of gases in monkeys expressly in the wintertime.

Experience in working with primates shows that, as compared to other species, these animals presented particularly marked defense and orienting-exploratory reactions. For this reason, the experimental situation (catching monkeys, immobilizing them and other conditions) could alter appreciable their physiological parameters, for example, leukocyte content of peripheral blood [18].

Our experiment established that there was gradual decline in amplitude of fluctuations of serum enzyme activity when blood was taken daily from the monkeys (Figure 2) due to decline of elevated parameters and some increment in low values. For this reason, in addition to decline of mean level, the monkeys presented a decrease in narrowing of range of fluctuations of serum enzyme activity when blood samples were taken daily and identical experimental conditions were strictly maintained. The observed dynamics of changes in serum enzyme activity should be interpreted as a manifestation of adaptation and attenuation of defense reactions of monkeys to the experimental situation.

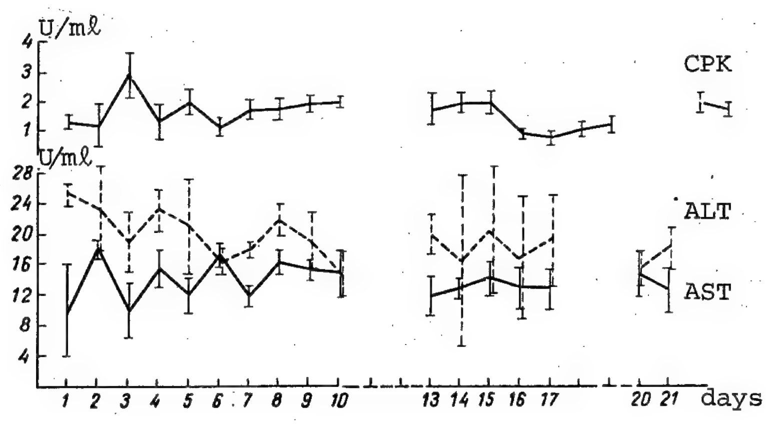

Figure 2. Dynamics of changes in blood serum CPK, AST and ALT activity with daily collection of blood samples from monkeys

Table 2. Comparative data on direction and informativeness of changes in blood serum enzyme activity in monkeys

Type of experimental factor	Direction of changes in enzyme activity in relation to standard ranges			Correlation between changes in enzyme activity			
	CPK	AST	ALT	$\rho_{CPK-AST}$	$\rho_{CPK-ALT}$	$\rho_{AST-ALT}$	R
Relative standard range	1,8—3,8	17,9—36,7	12,2—32,5	0,2	—0,12	0,1	0,2
Absolute standard range	0,07—5,3	4,0—54,0	4,0—55,0				
Orthostatic factors:							
20 min	++	—	—	—	—	—	—
1 h	+++	—	—	0,2	0,7	0,4	0,7
Immobilization:							
1 h	+	—	—	0,1	—0,1	0,2	0,2
24 h	+	+	+	0,6	0,4	0,3	0,95
48 h	+	+	+	—0,2	—0,6	0,3	1,0
Surgical trauma:							
1 h	+	—	—	0,3	0,6	0,6	0,8
6 h	+++	—	—	0,6	0,0	0,9	0,97
24 h	+	++	++	0,6	0,0	—0,3	0,3
48 h	——	—	+	0,9	0,3	0,6	1,0
Chronic neurotic state	++	——	—	0,14	0,11	0,8	0,8
Chronic neurogenic factor	+++	—	++	0,4	0,7	—0,2	0,8
Chronic arterial hypertension & myocardial ischemia	+++	——	+	—0,6	—0,5	—0,2	0,8
Salt toxicosis: 5 months	+++	—	—	—	—	—	—
6 "	+++	—	—	—	—	—	—
8 "	++			—0,43	0,1	0,3	0,3
Experimental myocardial infarction	—	+++	+++	—	—	0,51	—
Immunization with hemolytic streptococcus:							
1st immunization	—	+	+	0,3	—0,2	0,2	0,4
2d "	++	+	—	—0,7	—0,2	0,4	0,4
3d "	—	+	—	0,3	—0,1	—0,1	0,1
Infection with hemolytic streptococcus:							
immunized animals:							
4th day	+++	——	—	—	—	—	—
7th "	—	——	——	0,5	0,8	0,3	0,8
17th "	—	——	—	—	—	—	—
nonimmunized animals:							
4th day	+++	+	—	—	—	—	—
7th "	+++	——	—	0,5	1,0	0,5	1,0
17th "	—	——	—	—	—	—	—
Experimental dysentery:							
3d postinfection day	+++	—	——	0,6	0,3	0,6	0,6
immediately after treatment	+++	—	++	0,02	—0,1	0,3	0,4
long-term results (2 months)	+++	—	—	—0,3	0,04	0,4	0,5

Key: ρ) paired coefficient of correlation R) serial coefficient of correlation

When using the enzyme test, in particular, assaying serum AST and ALT activity, it is important to take into consideration the monkey's diet. Thus, changing them to granulated feed, which did not alter appreciably the standard range of fluctuation of aminotransferase activity, elicited a change in correlation between them due to relative increase in serum ALT activity (37.5±2.9 U/mℓ) and decline of AST activity (28.5±1.8 U/mℓ). This leads to decline of the Rittis coefficient (AST/ALT) from 1.22 to 0.58. Such a change could be indicative of increased metabolic activity of the liver with increase in functional load related to alteration of diet--additional fat and protein in the diet.

In the standardization studies, the mean CPK, AST and ALT were rather marked; there was frequent, reliable fluctuation as a function of age, sex, time of year, diet and other "situational" factors. However, in all cases these fluctuations were in the standard range. We always found a low correlation (Table 2) with regard to changes in CPK, AST and ALT activity. This circumstance led us to assume that a decline or elevation of serum enzyme activity within the standard range, in the absence of correlation between these changes, is a manifestation of differences in functional state of the body, organs and tissues, without elements of structural or functional disturbances. We believe that expressly this approach to interpretation of the observed changes in serum enzyme activity could prevent overestimation of so-called reliable changes in mean enzyme activity levels, if these changes occur within the standard range of fluctuations established for the activity of a given enzyme.

The different functional disturbances and pathological processes elicited by experimental factors were associated with persistent and marked enzymatic changes exceeding the range of standard fluctuations in CPK, AST and ALT activity. And, unlike the changes in enzyme activity of healthy monkeys, the enzymatic changes associated with pathological processes were characterized by appearance of reciprocal correlation between changes in activity of different enzymes and conformity of clinical and morphological manifestations to the pathological state under study (see Table 2).

As we have mentioned above, there are numerous clinical data indicative of the high diagnostic value of determining enzyme activity. At the present time, it is generally believed that an increase in serum enzyme activity is a manifestation of either a change in functional state or some pathological process associated with structural damage to body tissues. However, we failed to find clearcut criteria for significance of the observed changes in the existing literature. In most cases, mean activity of tested enzymes was compared. Sometimes, these values are related [by investigators] to so-called standard ranges which were usually obtained for a small sample. The lack of an objective means of distinguishing between an increase in serum enzyme activity due to functional stress or structural disturbances in body tissues is reflected in a number of instances in the inconsistency between clinical or pathoanatomical diagnoses, whereas in the case of experimental simulation of some pathological process it leads to exaggeration of degree of tissular destruction.

Our studies have demonstrated the need to make differential use of standards of CPK, AST and ALT activity, with consideration of age, sex, seasonal rhythm, as well as dietary distinctions. However, as can be seen from the above data,

the range of activity of the enzymes we studied was found to be rather wide. Thus, AST activity was in the range (Δx) of 4 to 54 U/mℓ, ALT activity 4 to 53 U/mℓ and CPK activity 0.08 to 5.25 U/mℓ. Within the range of these fluctuations, we observed rather reliable changes in mean values for enzyme activity as a function of both the main population parameters and a number of conditions and factors. For this reason, we took fluctuations of activity in the range limited by $\pm\sigma$ in relation to the mean value as the relatively normal range of enzyme activity. This range ($\Delta\sigma_x$) constituted 17.94-36.7 U/mℓ for AST, 12.2-32.5 U/mℓ for ALT and 1.84-3.8 U/mℓ for CPK. Levels of enzyme activity exceeding these ranges and contained in the range of fluctuations of $\pm 2\sigma$ or $\pm 3\sigma$ were assessed by us as differing or differing substantially from the mean standard level of activity of the enzyme in question, and we defined it as the absolute standard range (ΔX). However, it must be emphasized that these changes should be interpreted as manifestations of different functional states of organs and tissues. When serum enzyme activity is found to exceed the absolute standard range for the enzyme involved, one can suspect the presence of some pathological state associated with a destructive process. Table 2 lists summary data on direction and correlations for changes in activity of the enzymes tested in accordance with the standard ranges. The direction of changes in mean enzyme activity (X) is shown by a "0" and "+" or "-" signs. One "+" or "-" shows the tendency of change within the relative standard range ($\Delta\sigma_x$) with $P>0.05$. Two symbols refer to reliable changes in enzyme activity ($P<0.05$) beyond the $\Delta\sigma_x$ range and three symbols refer to reliable changes in mean serum enzyme activity exceeding the absolute standard range. In the right half of Table 2 are the corresponding paired (ρ) and serial (R) coefficients of correlation between changes in CPK, AST and ALT activity.

Examination of correlations between changes in blood serum enzyme activity has additional diagnostic implications. As mentioned above, there was no correlation between CPK, AST and ALT in healthy primates. The coefficients of correlation, both serial and between pairs, were quite low. In addition, correlations were demonstrable in the presence of a number of functional and pathological states and, what is particularly important, they corresponded to a certain extent to the severity of either functional stress or the pathological process. For this reason, we pay attention not only to the change in actual level of serum enzyme activity, but appearance of correlations between these changes.

We have singled out four main enzymodiagnostic states on the basis of our analysis of a wide range of physiological states (sex, age, seasonal fluctuations, different diet, phase of menstrual cycle), functional stress (orthostatic potion, immobilization, neurotisizing factors) and pathological states (surgical trauma, salt toxicosis, experimental myocardial infarction, dysentery, streptococcal infection).

1. A decline or elevation of CPK, AST and ALT activity within the relative or absolute standard ranges in the absence of correlation are assessed as manifestation of different functional physiological states of the body, organs and tissues, without elements of functional disturbances or structural damage.

2. Decrease or increase in enzyme activity within the relative standard range or beyond it, with a negative correlation, is a manifestation of active adaptive

stress associated with dissimilar permeability of cell membranes or different conditions of enzyme inhibition.

3. Increase or decrease in enzyme activity in excess of standard range, with positive or negative correlation between these changes, is viewed as a manifestation of chronic pathological process, which is demonstrable with an additional functional load.

4. An increase in enzyme activity beyond the absolute standard range, with positive correlation between changes in activity of different enzymes, is a manifestation of an acute destructive processes in body tissues.

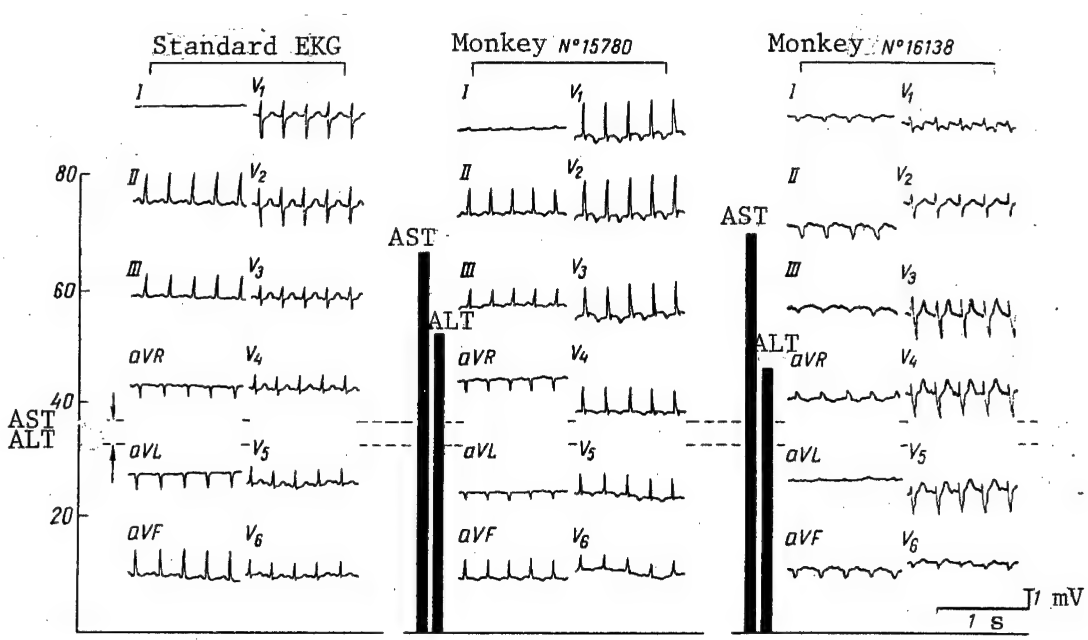

Figure 3. Electrocardiographic signs of cardiac pathology in monkeys with elevated blood serum transaminase activity. The boldface column shows top of relative standard range (+σ) of fluctuation of AST and ALT activity. Vertically--transaminase activity (U/mℓ)

Use of the criteria we propose is of definite practical value in mass screening of animals for special experiments, one of the mandatory prerequisites for which is absence of any functional or pathological disturbances. In addition, these criteria may be quite effective in assessing functional capacities and forecasting endurance of various functional loads by experimental animals.

Thus, when making such screening of primates on the program for preparations for the biomedical experiment aboard an artificial earth satellite, part of the animals was eliminated from the experiment on the basis of the enzymodiagnostic test. Subsequent special studies revealed various functional disturbances and pathological states in these animals. Figure 3 illustrates data referable to two such high risk animals, who subsequently developed pathological states against a background of elevated serum AST and ALT activity, which

exceed $\Delta\sigma_x$. One monkey developed acute myocardial ischemia (elevation of ST segment, inversion and development of negative T wave in all leads), while the other presented a stable block of His bundle crura. It should be noted that in high risk animals, corresponding to the third enzymodiagnostic state, there was development of serious complications (myocardial infarction, ulcerative enterocolitis, sudden death) from subsequent experimentation (surgery, isolation and rigid immobilization).

Our conceptions of the diagnostic informativeness of enzymodiagnostic tests are consistent to a considerable extent with the data of D. Wilkinson [5] and one of the recent systematic studies of serum CPK, AST and ALT activity conducted by T. Ye. Drozdova [19], who examined cosmonauts, hypokinetic subjects and people submitted to centrifugal accelerations. These studies and the data we have obtained are indicative of the expediency of including enzymodiagnostic tests in the combined program of working-up humans in clinical practice, as well as experimental animals for verification of health status or functional and pathological disturbances.

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UDC: 616.831-073.731-073.96

SYSTEM FOR AUTOMATIC ANALYSIS OF RHEOENCEPHALOGRAMS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 22 Jun 81) pp 81-83

[Article by I. V. Sokolova and Kh. Kh. Yarullin]

[Text] Automation of rheoencephalogram (REG) processing implies not only that routine processing time will be reduced, but that it will be possible to unify analytical methods on the basis of a single algorithm, use of which is possible with both manual and computer processing.

The ideology of the developed system for automatic analysis of REG is determined by a method that is based on singling out its arterial and venous components [1]. The software was prepared in the FORTRAN-IV algorithmic language. The hardware consists of a computer unit and telemetry equipment for reception of data.

The method for REG analysis stipulates that the rheographic curve $\mathrm{Reg}(t)$ for the duration of the cardiac cycle (T) reflects pulsating fluctuations in volumetric filling with blood of the examined vascular zone in such a manner that it can be rendered in the form of the sum of two components, $a(t)$ and $b(t)$ reflecting volumetric pulsation of the arterial and venous system, respectively.

$$\mathrm{Reg}(t) = a(t) + b(t), \quad t_0 \leqslant t \leqslant t_0 + \mathrm{T},$$

where t_0 is the starting point of the rheographic wave, t is current time and T is the period of the cardiac cycle.

The method includes identification of elements in the structure of the rheographic wave and determination of rheographic parameters that serve to diagnose functional states of the vascular zone examined. We submit below the flowchart of the algorithm of automatic REG analysis. The units [blocks] perform the following operations.

1. The primary processing unit filters [2] and differentiates [3] the REG, which was previously submitted to quantization in time at 15-ms intervals and in amplitude at no more than 0.04 V intervals in the signal range of 0-3 V from peak to peak, as well as singles out the period of the REG wave for

subsequent analysis. Distinction of the period is made with checking that conditions that permit processing have been met: according to scatter of maximum values of the first derivative, from which the period is singled out, according to scatter of minimum REG values for two adjacent periods; according to differences in period duration calculated from the first and second derivatives; according to scatter of REG values at the starting and ending points of the REG wave.

Flowchart of algorithm for automatic analysis of REG

1. Primary processing unit

↓

2. Unit for identifying structure elements

↓

3. Unit for forming REG parameters

↓

4. Unit for statistic processing

↓

5. Diagnostic unit

2. The unit for identification of structural elements of the REG wave makes use of the method of qualitative distinction of its arterial and venous components. The general nature of the components and summation thereof are illustrated in the Figure. The unit singles out the following components: points at which the arterial component begins (t_0); maximum value (amplitude) of arterial component (A) and its position (t_A); points of intersection by arterial component of isoline (t_B); maximum systolic value of venous component (V); incisura (I) and its position (t_I); dicrotic wave (D) and its position (t_D).

3. The unit for formation of rheographic parameters determines the following parameters for the period of the REG waves (in designations [symbols] adopted in the program): amplitude of arterial component (A, in ohms) to assess pulsed filling of the arterial system; maximum systolic value of venous component (V); mean rate of systolic build-up of venous component ($VV = V/(t_V - t_A)$ in Ω/s see Figure) (here t_A is the point for position of amplitude A, t_V is point for position of value of V); ratio of maximum systolic value of venous component V to amplitude A of arterial component (VA-V/A, as a percentage, characterizing peripheral vascular resistance); mean rate of decline of rheogram in the last quarter of the period--VYB = 4 Reg (3T/4) (in Ω/s; here Reg(3T/4) is the value of the rheogram at point t = 3T/4); ratio of venous efflux (VE = VYB/VV, %);

presence or absence of venous wave--KMVW (parameter of venous stasis, venous hypotension); ratio of incisura I to amplitude A of arterial component (IA = I/A, as a percentage) reflects peripheral vascular resistance PVR (of arterioles and capillaries); ratio of dicrotic wave D to amplitude A of arterial component (DA = D/A, %) which permits evaluation of PVR (mainly postcapillary); mean rheographic velocity of volumetric blood flow $F = (A + V)/T$ (in Ω/s).

Sample of printout of results of computer processing of REG

Date	25 Mar 81
Object	Salyut-6
Orbit	20079
Cosmonaut	D

Main REG parameters

Number of period L	1	2	3	4	5	6	7	8	9	10
Amplitude of A, mV	0,33	0,35	0,31	0,32	0,33	1,99	2,00	0,0	0,0	0,0
V/A ratio, %	49,64	47,11	66,89	46,94	57,21	48,76	49,45	0,0	0,0	0,0
I/A ratio, %	48,84	37,69	43,98	40,05	53,11	—0,23	—2,72	0,0	0,0	0,0
D/A ratio, %	50,77	45,86	43,96	40,05	67,56	100,37	99,97	0,0	0,0	0,0
Velocity VA, mV/s	1,45	2,94	2,08	2,34	2,72	18,91	19,09	0,0	0,0	0,0
Velocity VV, mV/s	1,05	1,56	2,32	0,76	1,38	9,22	9,44	0,0	0,0	0,0
Velocity VVE, mV/s	0,22	0,16	—0,03	0,16	0,29	8,20	10,02	0,0	0,0	0,0
VE ratio, %	20,45	10,01	—1,29	21,65	20,98	88,89	106,10	0,0	0,0	0,0
Velocity F in mV/s	0,60	0,63	0,62	0,55	0,63	3,65	3,84	0,0	0,0	0,0
Pulse rate, beats/min	74	72	71	71	74	74	76	0	0	0
MVW	1	1	1	1	1	1	1	0	0	0
Control number KBR	0	17	18	0	19	0	0	0	0	0
Control period KT	54	55	56	56	54	54	52	0	0	0

Mean values of REG parameters

	A	V/A	I/A	D/A	VA	VV	VVE	VE	ST	F	Pulse
Mathematical expectation	0,33	57,07	44,93	52,47	2,58	1,76	0,14	9,90	0,33	0,53	72
Top limit (P = 0.05)	0,37	75,23	59,16	76,53	3,40	2,66	0,44	30,34	0,37	0,54	74
Bottom limit (P = 0.05)	0,29	38,91	30,70	28,41	1,76	0,86	—0,16	—10,54	0,29	0,51	69
SKO [expansion unknown]	0,01	5,71	4,47	7,57	0,26	0,28	0,09	6,43	0,01	0,00	0

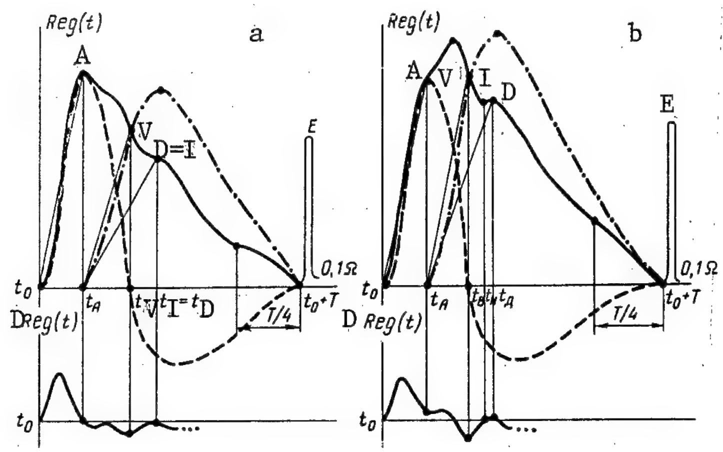
All parameters were determined for interval of 45 s; calibration signal not determined E = 1.0, HRK = 0.05. Number of readings 3

Results of computer analysis of REG

Condition of the examined vascular region is as follows:

Normal peripheral vascular resistance V/A 57.1
Normal capillary network I/A 44.9
Normal venous tonus VE 9.9
Venous wave
Filling of arterial system with blood A 0.33
Isoline shift 0.0

4. The unit for statistical processing puts out information about REG parameters over averaging interval of 45 s. Means are assessed for significance level of 0.1.



Arterial and venous components of REG of healthy man at age of 25 years (a) and patient with essential hypertension at age of 53 years (b) Reg(t)--REG in frontomastoid lead, DReg(t)--its first derivative--solid line; dash line--arterial component; dot-dash line--venous component; E--calibration signal. Other designations are explained in the text.

5. The unit for diagnosing functional state of cerebral vessels puts out information in the form of a column of diagnostic data: state of peripheral vascular resistance (parameters V/A, D/A); state of the capillary network (parameter I/A); venous tonus (parameter VE); presence or absence of venous wave (parameter KMVW); filling of arterial system (parameter A).

The operation of the system for automatic REG analysis was tested on data referable to three space missions, as well as REG obtained from the Nervous Disease Clinic of the First Moscow Medical Institute imeni Sechenov.

An example of the printout of results of computer processing of the REG is illustrated on the preceding page.

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BRIEF REPORTS

UDC: 629.78:612.014.47

PREFLIGHT EXAMINATION RESULTS USED TO FORECAST COSMONAUT ENDURANCE OF ORTHOSTATIC TESTS AFTER SPACEFLIGHT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 24 Nov 80) pp 83-85

[Article by V. A. Degtyarev, Yu. M. Dovzhenko, L. A. Larionova, V. G. Doroshev and N. A. Lapshina]

[Text] The flights of Soviet cosmonauts aboard the Salyut-6--Soyuz orbital complex demonstrated that it is possible for cosmonauts to work well in weightlessness for up to 6 months. At the same time, the question of predicting the postflight physical condition of cosmonauts is still a pressing one.

Our objective here was to investigate the possibility of forecasting the condition of the cosmonauts in the readaptation period on the basis of preflight examination findings.

Methods

We used the data from preflight studies of hemodynamics of crew members of Salyut-3, Salyut-4, Salyut-5 and Salyut-6 stations, which were recorded at rest and before functional tests, as well as the findings on the cosmonauts on the day they landed and on the 1st day of the recovery period, as our base material.

We recorded on each cosmonaut the parameters of the second program [1, 2] of the Polynome-2M equipment, which served to calculate the other parameters on a computer.

Of the numerous parameters obtained and calculated, we selected the following: heart rate (HR), arterial pressure--minimal (APm), dynamic mean (APm), lateral (APl), end (APe) and pulsed (APp), rate of propagation of pulse wave over arteries of the elastic type (Re), stroke (SV) and minute (MV) blood volume, actual specific peripheral resistance (SPR). We shall use vector to refer to the aggregate of these parameters referable to one reading on a cosmonaut.

Since a decline of orthostatic stability is the most marked manifestation of deconditioning of the cardiovascular system [3, 4], it is apparently of the

greatest interest to investigate the possibility of predicting endurance of the orthostatic test.

Table 1. Solving rule for classification of preflight observations and distribution of vectors in computer classes according to physicians' evaluation of endurance of postflight orthostatic tests

Comp. class	Solving rule	Total vectors in class	Mean orthostatic test endurance rating	Vectors referable to different evaluations of endurance by physicians, %		
				good	satisfactory	poor
3	APs⩽76	8	2.875	--	12.5	87.5
2	HR⩽60Λ APp⩽42 HR⩽60 ΛAPs⩽ 81	25	2.3	8	56	36
1	All cases that do not meet conditions 3 and 2	57	1.59	61.5	31.5	7

Note: The symbol Λ signifies the logical "and", symbol V--"or" [none shown in table]; Thus, condition 2 can be formulated in the following way: if HR⩽60 and APp⩽42 or HR⩽60 and APs⩽81, this case should be referred to the 2d class 2 (satisfactory endurance of postflight orthostatic test)

Postflight orthostatic test endurance was determined on the basis of a 5-point scale of integral scores, which was developed by V. V. Kalinichenko [5, 6]. We used only three scores: 1--good, 2--satisfactory and 3--poor. The obtained ratings were compared to preflight vectors. We analyzed 90 vectors measured in 10 cosmonauts; 37 of them corresponded to good endurance of orthostatic test after the flight, 33 to satisfactory and 20 to poor endurance.

It could have been assumed that postflight endurance of the orthostatic test is determined by duration of the flight. However, a comparison of endurance ratings to flight duration revealed that the coefficient of correlation between them does not differ appreciably from zero. This confirmed the validity of formulating the objective of our study.

In order to determine the correlation between the score for endurance of the orthostatic test and preflight hemodynamic parameters, we submitted all parameters grouped according to endurance scores to statistical processing. Only mathematical expectation of the first six parameters differed significantly, depending on scores for orthostatic test endurance. This enabled us to work with vectors consisting of 6 parameters rather than 10: HR, APm, APm, APl, APe, App; 90 vectors were used as a learning sample to form the rules for dividing postflight endurance of the orthostatic test into classes.

The classification was made by means of a program for "formation of descriptions of classes of object quality" [7]. This program for each distinguished class

makes it possible to obtain solution rules in the form of a multiple [many-placed] predicate (complex logical statement):

$$P_l = P_{1l} \wedge P_{2l} \dots \wedge P_{jl} \dots \wedge P_{il},$$

where $P_{1l}, P_{2l}, \dots, P_{jl}, \dots, P_{il}$ — are many-place predicates such as:

$$P_{jl} = P_{1jl} \dots \wedge P_{kjl} \dots \wedge P_{kil};$$

k is a whole number $0<k<m$; m is dimensionality of the vector; P_{1jl}, P_{2jl}, ..., P_{kjl} are single-place predicates, i.e., statements of the following appearance: $P_{kjl} = 1$, if $x_i * \alpha_i$, where there is the x_ith parameter; i changes from 1 to m, where m is dimensionality of the vector; * signifies the symbols $\geqslant$ or $\leqslant$.

If $x_i * \alpha_i$ is not satisfied, $P_k = 0$.

The number of tags contained in the description of each class, i.e., the link between j, k, i and l, the value of correlation *, boundary values for these tags α_i, length of description of each class i and k, and total number of classes l are determined automatically in the course of running the program.

Predicate P_l may assume the value of 0 or 1. If $P_l = 1$, the object is referable to class l. To identify the object (i.e., put the vector in one class or the other), the hierarchic identification [recognition] procedure is used. At first, one checks whether the object is referable to the poorest n class; then, if the answer is negative, its reference to class n-1 is checked (less poor), and so on until the object is identified. The program is written in PL1 language.

Table 2. Distribution of hemodynamic parameters obtained for cosmonauts before flights in computer classes

Station	Crew member	Flight duration	Most frequent value of			Rating for endurance of orthostatic test	Computer class
			HR	APm	APp		
Learning sample							
Salyut-4	CDR	30	63	76	35	Poor	3
" 5	FLE	48	44	74	40	"	3
" 3	CDR	15	45	90	38	Satisfactory	2
	FLE	15	56	81	40	"	2
" 4	CDR	63	60	82	41	"	2
	FLE	63	56	84	40	"	2
" 5	CDR	16	52	93	42	"	2
	FLE	16	68	91	42	Good	1
" 6	CDR	96	69	93	51	Satisfactory	1
	FLE	96	60	84	43	Good	1
Checking sample							
" 6	CDR	175	73	94	47	Good	1
	FLE	175	72	92	45	"	1
" 6	CDR	1 0	57	85	42	Satisfactory	2
	FLE	1 0	56	78	38	"	2

Results and Discussion

Before the flight (according to the data of V. V. Kalinichenko), all of the cosmonauts endured well the passive orthostatic test. On the 1st day after returning to earth, the endurance of the test was poor in two cosmonauts, satisfactory in six and good in two.

As a result of running the program for classification of objects, we formulated three computer classes, found the solution rule for determination of each class, mean score for endurance of the orthostatic test in a given class, total number of vectors in a given class and distribution of vectors among classes corresponding to good, satisfactory and poor endurance of the orthostatic test (Table 1).

Of the six selected parameters (Table), only three were included in the solving rules. This is attributable to significant correlation of the tags.

As can be seen in Table 2, the absolute majority of vectors obtained for subjects with poor endurance of postflight orthostatic test was included in the third computer class; the second computer class consisted mostly of vectors corresponding to satisfactory (50%) and poor (40%) endurance of the test.

The absolute majority of vectors measured in subjects with good (46%) and satisfactory (51%) endurance of the orthostatic test was contained in the first computer class.

Table 2 lists typical values of parameters found during preflight studies of some cosmonauts, score for their endurance of postflight orthostatic tests and corresponding computer classes.

We observed low mean dynamic AP in the preflight period in cosmonauts put in the third computer class (see Table 2). In view of their good endurance of the postflight orthostatic test, it can be assumed that individuals with marked hypotension could most likely become orthostatically unstable after prolonged weightlessness.

In order to check the obtained solution rules, we used the results of 140- and 175-day spaceflights aboard the Salyut-6 station. We examined 45 vectors according to the results of preflight examinations. There was complete confirmation of the validity of the proposed solution rules. Individuals with good endurance of the flight were put in the first computer class.

Thus, the solving rule we derived makes it possible to predict cosmonaut endurance of flights lasting up to 170 days.

Use of the "formation of descriptions of classes of object quality" program according to hemodynamic data made it possible to determine the minimum set of parameters for forecasting the condition of cosmonauts. The solving rule was derived for determining the classes of cosmonaut states in order to assess endurance of forthcoming spaceflights.

There are grounds to believe that, with further accumulation of factual material, the program can be used in the course of screening crew members for participation in future spaceflights.

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UDC: 629.78:[612.465.015.13+612.018:577.175.852+612.453.018:577.175.532

RENIN-ANGIOTENSIN-ALDOSTERONE SYSTEM AND ELECTROLYTE METABOLISM IN RAT BLOOD AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 24 Jul 81) pp 85-87

[Article by R. Kvetňansky, R. A. Tigranyan, A. Jindra and T. A. Viting (CSSR, USSR)]

[Text] It was shown that there is elevation of blood plasma renin activity in cosmonauts during spaceflights, without appreciable changes in concentration of aldosterone and electrolytes in blood [1]. In the postflight period, an increase in blood aldosterone concentration and plasma renin activity was noted in the case of short flights (7 days); however, in the case of long-term flights (96-140 days), a decrease was demonstrated in plasma renin activity and blood aldosterone concentration [3]; blood electrolyte concentration underwent insignificant changes in different directions in the postflight period. Our studies of blood plasma electrolyte concentration in rats after the experiments in Cosmos-605, Cosmos-690 and Cosmos-782 biosatellites failed to demonstrate changes in blood electrolyte concentration in flight animals, as compared to parameters of rats in control groups [4-6]. Previously, no studies had been pursued to assay blood aldosterone concentration and plasma renin activity in animals after completion of experiments aboard biosatellites of the Cosmos series.

Methods

These studies were conducted on male Wistar-SPF (Bratislava, CSSR) rats, which were flown in space for 18.5 days aboard Cosmos-1129 biosatellite. The animals were sacrificed 6-8 h after landing and on the 6th postflight day; some of the rats sacrificed on the 6th postflight day, as well as rats from the corresponding control and synchronous groups were submitted to immobilization stress for 150 min/day five times. We determined blood plasma aldosterone concentration and renin activity by the method of radioimmune analysis, as well as concentration of Na and K by atom-absorption spectrophotometry.

Results and Discussion

Immediately after the flight, the animals presented significant decrease in plasma renin activity, as compared to rats in the vivarium control and animals

in the synchronous experiment. Plasma renin activity increased 6 days after the flight, reaching the control level. In rats of all groups submitted to 5-fold immobilization stress we observed an increase in plasma renin activity, the most marked increase (though unreliable) being demonstrated in the flight group (see Table).

Aldosterone concentration (ng/mℓ) and renin activity (ng/mℓ/h) in rat blood plasma

Time of examination	Group	Aldo-sterone	Renin
6-8 h after flight (n = 7)	V_1	753±123	7,70±0,78
	F_1	1053±105	2,10±0,51
	S_1	620+68	5,69±1,01
6 days after flight (n = 6)	V_2	506+79	3,84±0,72
	F_2	763±161	5,54+0,54
	S_2	386+78	6,55±1,93
6 days after flt. + immobilization (n = 7)	V_3	1328+178	12,77+3,23
	F_3	1875+247	20,71±4,25
	S_3	1274±124	15,29±5,43
p		$F_1:S_1<0,001$	$F_1:V_1<0,001$ $F_1:S_1<0,01$

Key: V) vivarium control
F) flight
S) synchronous experiment

Immediately after flight animals landed, blood aldosterone concentration increased, as compared to the synchronous control. In flight animals sacrificed on the 6th postflight day, blood aldosterone concentration continued to be greater than in animals of corresponding control groups, but this increase was unreliable; 5-fold intensive immobilization stress led to an increase in blood aldosterone concentration on the 6th day of the readaptation period in all groups of animals, more so (but unreliably) in the flight group of rats (see Table).

Immediately after landing, we demonstrated a reliable decrease in concentration of blood Na and K in flight animals, as compared to both control groups. In flight rats sacrificed on the 6th postlanding day, Na and K concentration did not differ from levels in animals of the vivarium control and synchronous experiment. However, we demonstrated a reliable increase in concentration of K and decrease in concentration of Na in blood after 5-fold immobilization stress, to which animals were submitted during the 6-day readaptation period, as compared to parameters for the control and synchronous groups, which were also submitted to this stress.

We can interpret the obtained data in the following manner. It is known that a decline in blood K concentration diminishes aldosterone secretion by the adrenals; for this reason the low K content in blood of flight animals cannot be considered the cause of increase in blood aldosterone concentration. Conversely, the increase in blood aldosterone concentration can be interpreted as the cause of decrease in blood K concentration, due to increased excretion of this electrolyte by the kidneys. The decrease in blood Na concentration could be the cause of increase in aldosterone concentration; however, this mechanism occurs through the renin-angiotension system. The decrease in plasma renin concentration in flight animals immediately after landing is in contradiction with this statement. Evidently, the increase in aldosterone concentration is related to the spaceflight and is a residual elevation, most probably due to the increase in aldosterone concentration during the spaceflight. From this point of view, aldosterone, being the more inert element of the renin-angiotension-aldosterone system, remains high and inhibits renin secretion. The high concentration of aldosterone activates processes of

deposition of Na, which is instrumental in decreasing the concentration of Na in blood.

There was activation of the renin-angiotensin-aldosterone system in animals submitted to immobilization stress after the flight. The increase in plasma renin activity could be due to decrease in blood Na concentration. The increase in concentration of aldosterone is due to the high activity of blood renin, on the one hand, and increase in blood K concentration, which directly stimulates aldosterone secretion by the adrenals, on the other hand. The primary cause of decrease in blood Na concentration could be the spaceflight, during which there was, perhaps, loss of this electrolyte and, secondarily, enhanced by the renin-angiotensin-aldosterone system, which activates processes of deposition of Na in the organism. It is difficult to explain the increase in blood K concentration.

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UDC: 629.78:612.173.1.018:577.175.522/.523

EPINEPHRINE AND NOREPINEPHRINE CONCENTRATIONS IN RAT CARDIAC VENTRICLES AND ATRIA AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 24 Jul 81) pp 87-89

[Article by R. Kvetňansky and R. A. Tigranyan (CSSR, USSR)]

[Text] The studies pursued in the Cosmos-782 and Cosmos-936 experiments revealed that a prolonged spaceflight leads to increase in concentration of total catecholamines (CA) in the rat myocardium; however, this elevated CA level in the myocardium was not related to change in synthesis or degradation of CA in the heart, as indicated by the unchanged activity of dopamine-β-hydrolase (the CA-synthesizing enzyme), monoamine oxidase and catechol-O-methyltransferase (enzymes of CA degradation) [1-3]. These data warranted the assumption that there were functional changes in the sympathetic nervous system and, probably, the heart itself during the spaceflight. Our objective here was to corroborate the results of prior studies, but on different parts of the heart, rather than the whole heart; we analyzed separately the demonstrable concentrations of norepinephrine (NE) and epinephrine (E) in the four compartments of the myocardium.

Methods

The studies were conducted on male Wistar-SPF rats (Bratislava, CSSR) which had been flown in space for 18.5 days in the Cosmos-1129 biosatellite. The animals were sacrificed 6-8 h after landing and on the 6th postflight day; some of the animals sacrificed on the 6th postflight day, as well as animals in the corresponding control and synchronous groups, were submitted to immobilization stress five times, for 150 min per day. After decapitating the rats, we isolated the myocardium, cleaned it and divided it into four parts--left ventricle, right ventricle, left atrium and right atrium. E and NE were assayed separately for each compartment by the radioenzymatic method [4, 5].

Results and Discussion

NE was unevenly distributed in the myocardium; the maximum concentration was demonstrated in the right atrium, less in the left atrium and right ventricle, and the least in the left ventricle (Tables 1 and 2).

Table 1. CA content in rat heart ventricles (M±m, ng/g)

Group	Time of examination	Left ventricle		Right ventricle	
		E	NE	E	NE
1: V	After 6-8 h ($n = 7$)	30,9+9,8	376±31	26,4±4,8	848±48
F		41,3+7,1	603+32	40,9±4,4	1051±104
S		37,0±9,7	636±47	24,1±5,9	982±106
2: V	After 6 days ($n = 6$)	36,1±14,6	524±73	23,0±5,8	1106±152
F		21,1+2,3	462±50	26,0±7,7	1012±105
S		15,9±3,0	474±52	20,1±1,7	1018±132
3: V	After 6 days + immobilization	33,3±8,4	302±44	48,1±7,3	746±50
F		28,9+5,4	258±32	58,4±11,9	686±86
S		23,7±3,9	234±21	29,5±4,2	507±38
Reliability			$F:V_1$ $P<0{,}001$ $S_1:V_1$ $P<0{,}001$	$F_1:V_1$ $P<0{,}05$ $F_1:S_1$ $P<0{,}05$ $F_3:S_3$ $P<0{,}05$ $V_3:S_3$ $P<0{,}05$	$V_3:S_3$ $P<0{,}01$

Key for this and Table 2:
V) vivarium control F) flight S) synchronous experiment

Table 2. CA content in rat heart atria (M±m, ng/g)

Group	Time of examination	Left atrium		Right atrium	
		E	NE	E	NE
1: V	After 6-8 h ($n = 7$)	75,8±23,7	963±207	142,4±28,4	3599±421
F		85,2±20,1	458±254	48,6±6,1	2359±206
S		41,2±11,1	929±150	66,9±9,6	2725±226
2: V	After 6 days ($n = 6$)	29,3±8,2	1057±115	54,7±8,6	2047±284
F		42,1±3,1	323±150	68,5±13,0	2634±409
S		17,2±2,4	774±142	27,2±5,1	1979±182
3: V	After 6 days + immobilization ($n = 7$)	65,6±10,4	619±125	96,5±20,2	1752±375
F		57,4±15,8	256±124	99,5±15,4	1425±118
S		37,7±6,3	79±39	68,0±10,0	1328±155
Reliability		$F_2:S_2$ $P<0{,}001$ $F_3:S_3$ $P<0{,}05$	$F_2:V_2$ $P<0{,}01$ $S_3:V_3$ $P<0{,}01$	$F_1:V_1$ $P<0{,}05$ $S_1:V_1$ $P<0{,}05$ $S_2:V_2$ $P<0{,}05$ $F_2:S_2$ $P<0{,}05$	$F:V_1$ $P<0{,}05$

In rats sacrificed immediately after landing we found an increase in NE concentration in the ventricles (reliable for the left ventricle), whereas in the atria, on the contrary, it diminished (reliably in the right atrium)--see Tables 1 and 2. On the 6th postflight day we observed a decline of NE level in

the left atrium (see Table 2); no reliable changes in NE concentration were demonstrated in other parts of the heart (see Tables 1 and 2). Repeated immobilization of rats after the experiment elicited a decline of NE level in all groups of animals in all compartments of the heart; however, these changes were unreliable. A reliable decrease in EN content was demonstrated in the group of animals of the synchronous experiment, as compared to the vivarium control, in the right and left atria (see Tables 1 and 2).

In the flight rats, E concentration was higher in the atria than the ventricles (see Tables 1 and 2). Immediately after landing, E concentration was high in the right ventricle and, on the contrary, low in the right atrium, as compared to the vivarium control; no reliable changes in E concentration were noted in the left heart (see Tables 1 and 2). E concentration increased in both atria 6 days after landing; however, this increase was reliable only in comparison to the synchronous control (see Table 2); the changes in E concentration in the ventricles were unreliable (see Table 1). After 5-fold immobilization of rats on the 6th postflight day, we observed an increase in E concentration in the right ventricle and left atrium; however, these changes were reliable only in relation to the synchronous control group (see Tables 1 and 2).

In our previous studies, we demonstrated elevation of CA level in the rat myocardium after a spaceflight [1-3]. In the experiment aboard Cosmos-1129 biosatellite, we demonstrated an increase in NE and E concentrations only in the cardiac ventricles, whereas in the atria, there was a decrease, particularly of NE. At first glance, it would appear that these findings are inconsistent with data obtained in the preceding biosatellites, since the highest concentration of CA was noted in the atria, while they showed a drop of CA level, rather than the expected rise. However, if we consider the fact that most of the mass of the heart is concentrated in the left ventricle, expressly elevation of CA in this part of the heart is the cause of changes in the homogenate of the whole myocardium. For this reason, it can be considered that the increase in CA in the rat heart immediately after the spaceflight was proven in the Cosmos-1129 biosatellite experiment. On the other hand, we should mention the similar decline of NE level in the left atrium of all rats flown in space. It can be considered that this part of the heart is the most sensitive to factors related to prolonged exposure to weightlessness, since an appreciable drop of NE level was demonstrated both immediately after landing and 6 days after the flight. Repeated immobilization led to decline of NE level and elevation of E mainly in the ventricles. We have demonstrated that, under chronic stress conditions, there is no drop of CA level in the rat heart, so that it can be assumed that rats were not submitted to intensive stress during the spaceflight. Maximum changes in concentration of E, which is an exogenous CA for the heart, absorbed primarily from blood, were demonstrated in the right ventricle and in the right heart in general.

Our findings confirm the hypothesis that there is elevation of CA level in the heart after spaceflights, probably due to diminished functional load in weightlessnesss. Thus, this state is obviously not a chronic stressor. On the other hand, there are some parts of the heart (for example, the left atrium) that react specifically to spaceflight by a drop of NE level. Further investigations are needed to determine the significance of these changes.

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UDC: 629.78:612.129:577.

RAT BLOOD PLASMA CORTICOSTERONE AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 31 Jul 81) pp 89-90

[Article by R. Kvetňansky and R. A. Tigranyan (CSSR, USSR)]

[Text] Rat blood plasma corticosterone is a good indicator of the stress reaction. The level thereof rises appreciably under acute stress, as well as repeated stress as long as the stressor is active. Previous experiments aboard the Cosmos-782 and Cosmos-936 biosatellites revealed that corticosterone (B) rose significantly in plasma of animals sacrificed immediately after landing [1, 2]. Our objective was to determine whether prolonged weightlessness is an intensive stressor or not. On the basis of elevation of level of B in blood immediately after landing we were unable to determine whether this resulted from weightlessness or stressors associated with landing of the biosatellite.

We have demonstrated that plasma B level remains significantly elevated for several hours in the postimmobilization period, in rats submitted to stress for the first time, whereas it returned to the control level as early as 30 min after the last immobilization in animals that were immobilized repeatedly [3]. We wanted to use these data to answer the question of whether prolonged weightlessness is a chronic activator of the adrenal cortex. We proceeded from the assumption that, if the organism is subject to chronic stress during the spaceflight, it should react after landing to the stressor in the form of rapid drop of B level in plasma in the postimmobilization period. If, however, we were dealing only with acute stress, which was related to biosatellite landing, the level of plasma B should remain elevated after the flight, in the postimmobilization period after using this stressor on earth.

Methods

We conducted these studies on male Wistar-SPF rats (Bratislava, CSSR), which had been flown in space for 18.5 days aboard the Cosmos-1129 biosatellite.

We immediately submitted rats that returned from the spaceflight to immobilization stress [3], taking blood samples from their tail just prior to immobilization, in the 150th min of immobilization and 30 min after termination of immobilization. We took blood samples from the tail on the same schedule after the

2d and 4th immobilizations. We assed B concentration in blood samples taken from the tail, as well as after decapitating the rats, by the method of competitive binding with protein. Adrenal B concentrations was determined as described in [4].

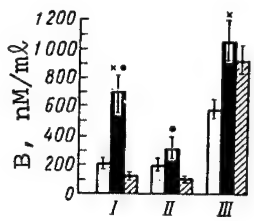

Figure 1.

B concentration in plasma taken when rats were decapitated. White columns--vivarium control; black--flight; crosshatched--synchronous experiment

I) immediately after landing
II) 6 days after landing
III) 6 days after landing + immobilization

× shows reliability p<0.01, as compared to vivarium control, and dot p<0.05, as compared to synchronous experiment

Here and in Figures 2 and 3, mean data (M±m) from 6-7 readings are given

Corticosterone content (nanomole/g) in rat adrenals

Time of examination	Group	Cortico-sterone level
After 6-8 h (n = 7)	Y_1	18,7±4,3
	F_1	34,3±8,7
	S_1	19,0±1,8
After 6 days (n = 6)	Y_2	24,9±6,8
	F_2	34,9±6,9
	S_2	25,5±6,3
After 6 days + immobilization (n = 7)	Y_3	72,6±15,6
	F_3	82,8±12,1
	S_3	76,8±9,3

Key:

Y) vivarium control
F) flight
S) synchronous experiment

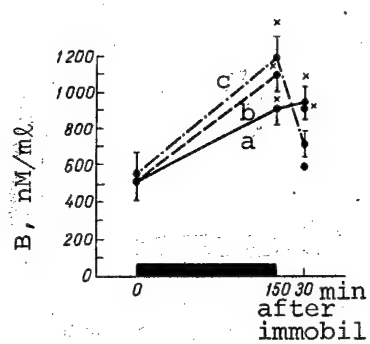

Figure 2.

B concentration in flight rat blood plasma taken from tail after 1st (a), 2d (b) and 4th (c) immobilization. × shows reliability p<0.01, as compared to B level prior to immobilization; dot shows reliability p<0.01, as compared to level of B in 150th min of immobilization

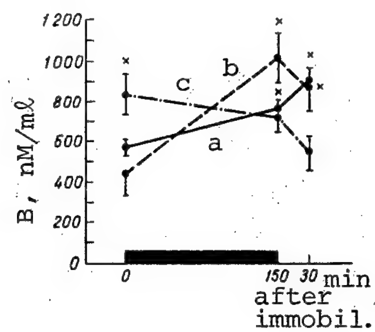

Figure 3.

Concentration of B in control rat blood plasma taken from tail after 1st (a), 2d (b) and 4th (c) immobilization; × shows reliability p<0.01, as compared to level of B before immobilization

Results and Discussion

The level of B in blood plasma obtained when the rats were decapitated rose significantly in flight rats immediately after landing, as compared to both

control groups. Six days after landing, plasma B concentration in flight animals did not differ from that demonstrated in the vivarium control, although it was somewhat higher than in rats of the synchronous experiment. Repeated immobilization in the postflight period was associated with appreciable elevation of plasma B in flight animals, as compared to the vivarium control (Figure 1).

In the adrenals, the concentration of B was elevated in animals flown in space, but this elevation was not reliable (see Table).

Assay of B in blood taken from the tail of rats immobilized after landing revealed that its concentration increased after the first immobilization and remained high even 30 min after termination of immobilization. Although the plasma B level rose reliably after the 4th immobilization, it was in the range of control values 30 min after termination of immobilization (Figure 2). Similar findings were made in control rats (Figure 3).

Plasma B level rose significantly in flight rats immediately after landing. B level rose under the influence of immobilization stress, both in the period it was used and after termination of immobilization. This shows that flight animals did not react to immobilization stress like the rats submitted to chronic stress, rather like rats following acute stress. For this reason, we assume that the elevated level of blood plasma B in flight rats immediately after termination of the flight was attributable to factors related to landing the biosatellite, rather than the prolonged effect of weightlessness. The fact of the matter is that when flight animals were submitted to immobilization stress four times (150 min per day) the level of plasma B after termination of immobilization dropped to control values. Thus, repeated exposure to this stressor overtly lowered B during the period after termination of immobilization, whereas the stressor present immediately after landing did not cause such changes.

Our findings give us every reason to assume that the adrenocortical system was not subjected to intensive chronic stress during the long-term, 18.5-day, spaceflight.

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UDC: 629.78:612.398.192

DEOXYRIBONUCLEOPROTEIN AND NUCLEIC ACID CONTENT OF RAT TISSUES AFTER FLIGHT ABOARD COSMOS-936 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 (manuscript received 26 Jun 81) pp 91-93

[Article by E. Mišurova, R. A. Tigranyan, K. Kropačeva and M. Praslička (CSSR, USSR)]

[Text] A change in deoxyribonucleoprotein (DNP) content of lymphatic and hemopoietic tissues is elicited by a number of physicochemical factors, such as ionizing radiation, cytostatic agents, glucocorticoids and formol [1-4]. Damage to DNP is manifested by a change in levels of soluble polydeoxyribonucleoproteins (PDRN), which are DNP segments, apparently nucleosomes [5]. Elevation of PDRN level is related to pyknosis and death of sensitive cells, mainly lymphocytes and erythroblasts, and it is associated with a decrease in DNP and RNA content of tissues. Elevation of PDRN level is the result of brief exposure to a nonspecific factor. Since elevation of PDRN level was demonstrated in rats flown aboard the Cosmos-782 biosatellite [6], it was interesting to determine whether use of artificial gravity (AG) aboard Cosmos-936 biosatellite would prevent these changes.

Methods

The studies were conducted with male Wistar-SPF (Bratislava, CSSR) rats flown for 18.5 days in space aboard the Cosmos-936 biosatellite. The experimental conditions were described in a previously published work [7].

We assessed DNP changes on the basis of assaying its concentration in tissues and level of soluble PDRN [1]; PDRN content of the soluble fraction and DNP of the insoluble fraction were expressed in milligrams per gram wet tissue.

Nucleic acids were assayed by the method of Tsanev and Markov [8], and expressed in milligrams P per 100 g wet tissue (concentration) and in milligrams P per organ (total content). The obtained data were processed by means of analysis of variation and the Duncan test [9].

Results and Discussion

Immediately after the flight, PDRN level more than doubled in the spleen of rats submitted to weightlessness, as compared to the vivarium and synchronous control

(Figure 1). Similar but even more distinct changes were demonstrated in the spleen of rats flown in Cosmos-782 biosatellite [6]. Use of AG aboard the biosatellite did not prevent these changes in the spleen, whereas centrifugation on earth (corresponding synchronous control group) elicited even more drastic elevation of PDRN, as compared to the other groups of animals. The concentration and, mainly, amount of DNP were diminished in all groups of the flight and synchronous experiment, as compared to the vivarium control, by 15-45%; the quantitative changes in RNA were insignificant. A comparison of DNP and RNA levels in both flight experiment groups of animals revealed that use of AG had some positive effect. There was recovery of all tested parameters of the spleen 25 days after the flight (see Figure 1).

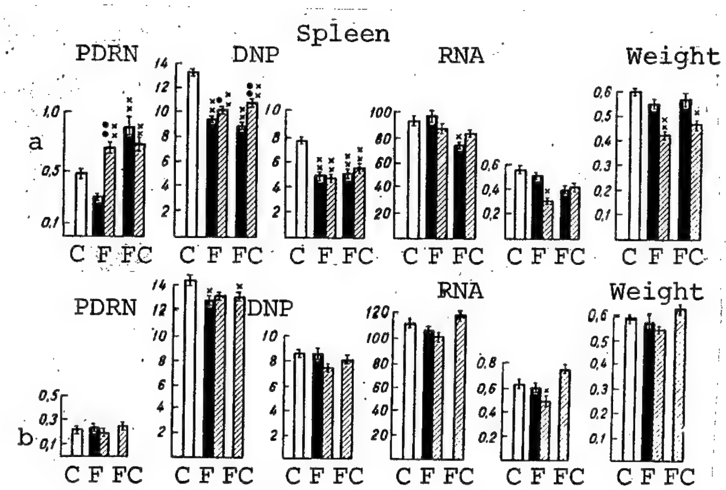

Figure 1. Concentration of PDRN (mg/g), DNP (mg/g) and RNA (mg P/100 g), total DNP (mg/organ) and RNA (mg P/organ) in rat spleen and weight of organ (g) 6 h (a) and 25 days (b) after flight

Here and in Figures 2-4:
C) control
F) flight
FC) flight + centrifuge
Black columns--synchronous experiment; crosshatched--flight.
Mean data for 6 animals are given. One and two asterisks show $P<0.05$ and $P<0.01$, respectively, in relation to parameters for control group; one and two circles show $P<0.05$ and $P<0.01$, respectively, in relation to animals in the synchronous experiment group

The PDRN level rose by more than 2 times 6 h after landing in the thymus of rats submitted to weightlessness, as compared to the parameters for animals in the vivarium control; however, in rats centrifuged in flight, as well as the corresponding synchronous control group, it did not differ from the vivarium control. There were insignificant quantitative changes in DNP and RNA. On the 25th day of the recovery period, all of the measured parameters were at the level of the vivarium control (Figure 2).

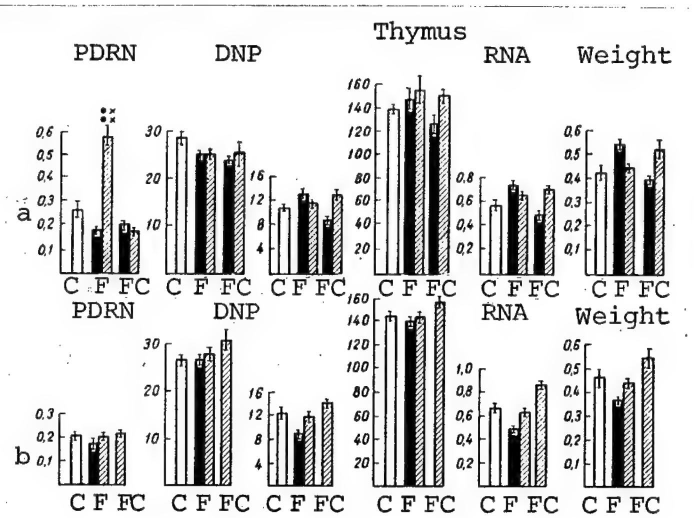

Figure 2.
Concentration of PDRN (mg/g), DNP (mg/g) and RNA (mg P/100 g), total DNP (mg/organ) and RNA (mg P/organ) in rat thymus and organ weight (g) 6 h (a) and 25 days (b) after flight

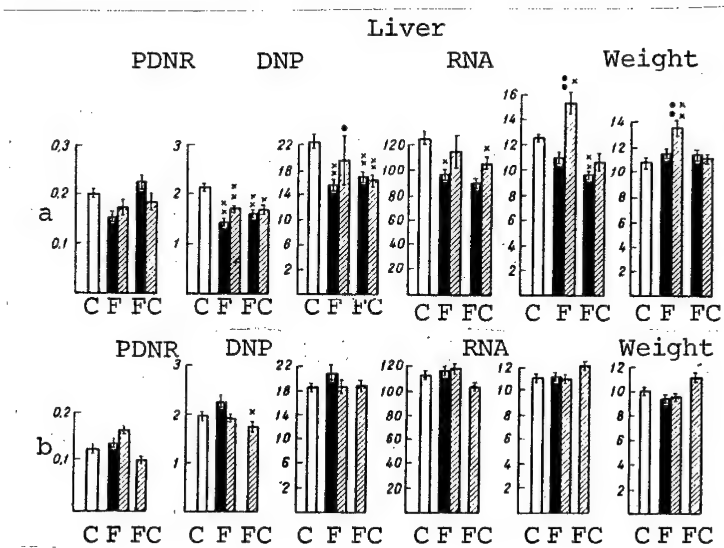

Figure 3.
Concentration of PDRN (mg/g), DNP (mg/g), RNA (mg P/100 g), total DNP (mg/organ) and RNA (mg P/organ) in rat liver and organ weight (g) 6 h (a) and 25 days (b) after flight

The PDRN level in the liver of rats in all experimental groups did not differ immediately after landing from that of animals in the vivarium control. The concentration and amount of DNP in both groups of the flight and synchronous experiment dropped, as compared to the vivarium control; there were analogous changes in quantitative parameters of RNA. It should be noted that the relatively high DNP and RNA content of the liver of rats submitted to weightlessness was related to an increase in weight of this organ. In both groups of flight and synchronous experiments, the rats showed recovery of all parameters to control levels 25 days after the flight (Figure 3).

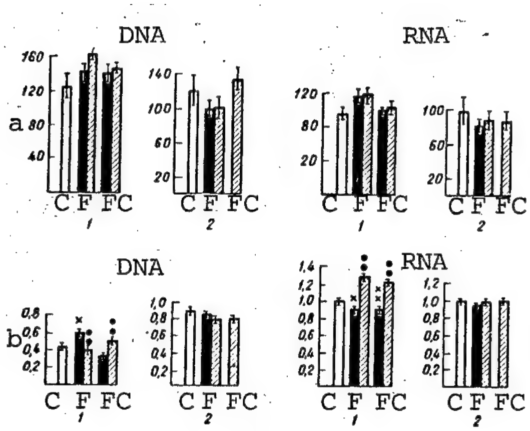

Figure 4.
Concentration of DNA and RNA in bone marrow (a, mg/100 g) and blood leukocytes (b, mg/100 mℓ) 6 h (1) and 25 days (2) after flight

The concentration of DNA and RNA in bone marrow of animals in all experimental groups did not differ from animals in the vivarium control (Figure 4). Analogous findings were made in blood, where the concentration of nucleic acids in both flight groups of rats did not differ from the vivarium control; however, it was changed in animals used in the synchronous experiment (see Figure 4).

The data obtained on rats submitted to weightlessness coincide entirely with our findings in the experiment aboard the Cosmos-782 biosatellite [6], although they were less marked. On the basis of data in the literature [1, 2, 10] and our own results [6, 11], it can be assumed that the elevation of PDRN level in the spleen and thymus of rats submitted to weightlessness, which was demonstrated several hours after spaceflights, can be considered proof of injury (degradation) of part of the DNP at the last phase of the flight, i.e., during the landing. Use of AG prevented degradation of DNP in the thymus, but not in the spleen; this difference is apparently attributable to the difference between cell populations of the thymus and spleen. At the same time, the levels of DNP and RNA in the spleen and bone marrow of flight groups of rats are indicative of a certain positive effect of AG on these organs as well. As for the data pertaining to the liver, they do not unequivocally confirm the positive effect of using AG.

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CURRENT EVENTS

MEETING OF EDITORS OF SOVIET AND AMERICAN AEROSPACE JOURNALS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 p 93

[Article by editorial board of KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA]

[Text] There was a meeting of prominent staff members of the Institute of Biomedical Problems, USSR Ministry of Health, and editorial board of KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA [Space Biology and Aerospace Medicine] with Doctor S. D. Leverett, editor of the journal, AVIATION SPACE AND ENVIRONMENTAL MEDICINE, which is published by the American Aerospace Medical Association.

Doctor S. D. Leverett is well-known in our country as one of the leading specialists in physiology of accelerations. He is an active member of the American Aerospace Medical Association and a member of the International Academy of Aerospace Medicine; he is the recipient of numerous prizes and awards for achievements in the area of aerospace medicine.

Doctor S. D. Leverett was appointed editor of the above-mentioned journal in 1980, having replaced J. P. Marbarger, who has retired.

At the meeting with Soviet specialists, Dr S. D. Leverett told about organization of editorial and publishing work for his journal, and the intent to acquaint the American reader more extensively with the works of Soviet specialists in the field of space biology and aerospace medicine.

An agreement was reached on establishing business contacts between the editorial boards of both journals.

BOOK REVIEWS

UDC: 629.78:612.32+612.33(049.32)

NEW BOOK ON SPACE GASTROENTEROLOGY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 pp 94-95

[Review by V. I. Fofanov of book "Kosmicheskaya gastroenterologiya" (Space Gastroenterology) by K. V. Smirnov and A. M. Ugolev, Moscow, Izdatel'stvo "Nauka", 1981, 276 pages]

[Text] The monograph by K. V. Smirnov and A. M. Ugolev, "Space Gastroenterology," is a fundamental work that contains the results of many years of investigation of digestive organs as related to exposure to spaceflgiht factors.

For the first time, a comprehensive analysis was made in this book of secretory and motor function of the gastrointestinal tract in the case of both manned and animal spaceflights, as well as simulation of the effects of spaceflight factors. The enormous experimental material enabled them not only to establish the phenomenology of functional changes in the digestive system with exposure to spaceflight factors such as weightlessness, accelerations and hypokinesia, but to determine the role of different regulatory mechanisms in development of the demonstrated changes in secretory and motor functions of the gastrointestinal tract.

The timeliness and novelty of this monograph are unquestionable. The increased duration of spaceflights is putting more and more insistently to space medicine the task of studying the digestive system, a system which is the active instrument of metabolism, which not only effects hydrolysis and transport of nutrients, but corrects the metabolic resources of the body.

At the present time, thanks to the discovery by A. M. Ugolev, of parietal or membrane digestion, his definition of the role of enteric hormones in the body, as well as a number of new investigations of processes of incretion, excretion and recretion of digestive enzymes, theoretical gastroenterology has made it possible to interpret from utterly different vantage points the changes in the digestive system detected after spaceflights.

In spite of its seemingly applied nature, the book by K. V. Smirnov and A. M. Ugolev makes a large contribution ot theoretical gastroenterology. The authors have discussed extensively the problem of adaptive and nonadaptive changes in the gastrointestinal tract during spaceflights; they submit new data that are

of great interest to the problem of effects of extreme factors on the body. In solving this problem, determination was made of the reactions of the gastrointestinal tract to various stages of exposure to an extreme stimulus, dependence of changes in digestive functions on intensity and duration of exposure to a factor, as well as on the initial functional state of the digestive system.

Information about the distribution of enzyme activities in the gastrointestinal tract is of great interest. It provides a new idea about the gastrointestinal tract as a self-regulating system.

The logically constructed chain of investigations enabled the authors to differentiate between the roles of different spaceflight factors during flights differing in duration.

The book consists of eight chapters. Chapter 1 deals with general problems of space gastroenterology. Much space is devoted in this chapter to questions pertaining to physiology of the digestive system, new conceptions of mechanisms of regulation of digestive functions, adaptive changes in structure and function of the gastrointestinal tract.

This chapter describes the main types of digestion, as well as membrane digestion, which was discovered relatively recently; it discusses new trends in physiology.

There is an extremely relevant section, in which the enteric ["enterine"] (gastrointestinal) hormonal system is described, in accordance with current conceptions, as the most important element of regulation of metabolic processes in the organism.

The last section of Chapter 1 deals with methodological approaches used to examine the gastrointestinal tract in space gastroenterology. Since it is impossible to study the effect of weightlessness on function of the digestive system during an actual spaceflight, experimental models have now been developed, which permit investigation of the different aspects of weightlessness under ground-based laboratory conditions.

The authors dwell in detail on the significance of model experiments to the study of the effect of weightlessness on the functional state of digestive system organs, as well as feasibility of extrapolating to man the results obtained from animal experiments.

Chapter 2 of the monograph is of great interest. It describes the enzyme systems of the gastrointestinal tract of man after spaceflights lasting 2 to 175 days. A vast amount of unique material has been integrated and submitted, which characterizes the enzymatic systems of the stomach, pancreas and small intestine after both short- and long-term spaceflights. The authors indicate that the depth of changes in proteolytic, amylolytic and lipolytic complexes of digestive enzymes is directly related to duration of weightlessness; however, the tendency toward normalization of elicited changes in the postflight period is indicative of the functional nature of demonstrated changes.

Chapter 3 deals with investigation of the digestive system of animals flown in the Cosmos-782 and Cosmos-936 biosatellites. This chapter is remarkable for the fact that it submits not only the results of studies of digestive organ function in rats, but morphological description of these organs.

The teams of sepcialist-morphologists who were involved in this work conducted extremely valuable combined studies of organ and tissue ultrastructure. These studies made it possible to evaluate the digestive system of rats after being exposed to weightlessness, as well as animals used in synchronous ground-based experiments and control groups, to differentiate changes elicited under the direct effect of weightlessness, assess the effect of artificial gravity as a means of preventing the undesirable effects of weightlessness. Indications of the morphologically confirmed hypersecretory syndrome, which develops during flights, is of extremely great practical importance. At the stage studied, the hypersecretory syndrome does not lead to development of gastric ulcer, but causes one to be on guard and makes it imperative to conduct further special studies in this direction.

The next chapters of the monograph deal with investigation of enzyme-secreting function of the digestive system of man and animals in model studies. Some extremely interesting data are submitted on the functional state of the gastro-intestinal tract of people who have spent long periods of time (49, 120 and 182 days) on strict bed rest. The authors demonstrated convincingly that if man is submitted to antiorthostatic [head down] hypokinesia for 49 days, this leads to increased stimulation of juice secretion and acid production, intensification of bile production and depression of motor function of the stomach. With regard to 182-day antiorthostatic hypokinesia, it should be noted that the results of examining the digestive system after it were analogous in many respects to the findings after a real 175-day spaceflight. On the one hand, this stresses once more the validity of the selected models; on the other hand, it cannot help but interest a wide circle of clinicians dealing with various forms of pathology where prolonged bed rest is recommended as a therapeutic regimen.

With reference to the material submitted by the authors, we should like to stress the fact that this work is impressive in its breadth and depth of issues covered. Indeed, during spaceflights, not only weightlessness and hypokinesia, but a set of other experimental factors, such as accelerations (when the craft is launched and lands), vibration, ionizing radiation and many others are involved. The monograph cites data in the literature concerning diverse factors, as well as the results of studying the effects of transverse accelerations differing in magnitude and duration on the functional state of digestive organs.

Much attention is devoted in this book to mechanisms of effects of spaceflight factors on the digestive system. The significance of different conditions of exposure to extreme factors to development of functional changes is discussed quite comprehensively and in depth, namely, the role of intensity and duration of exposure to a given agent, significance of conditioning for experimental factors, dependence of changes in digestive organ function on their initial functional state.

We were impressed by the section that deals with the significance of the vagus with exposure to accelerations. The authors used methods of direct and pharmacological transection of the vagus nerve, which enabled them to establish the leading role of the parasympathetic nervous system in mechanisms of changes in the digestive system.

Use of pharmacological correction of functional changes in organs of the digestive system under the effect of hypokinesia and accelerations made it possible to recommend a number of products for normalization of changes in digestive system functions during spaceflights.

Chapter 8 discusses the general patterns of reactions of the digestive system during spaceflights. Much attention is given to questions of correction and prevention of changes in the digestive system, role of initial functional state of the digestive system in professional screening and training.

The authors demonstrated convincingly, on the basis of extensive facts and material in the literature, that it is necessary to continue with studies of the digestive system during long-term spaceflights.

On the whole, the book by K. V. Smirnov and A. M. Ugolev is one of the first generalizations of knowhow gained in research in the field of space gastroenterology. Unfortunately, the authors gave no attention at all to questions of nutrition of man as related to being in a life-support system that is developed on the basis of the function of biological components. It can be hoped that subsequent works will fill the gaps in this area of research.

The monograph by K. V. Smirnov and A. M. Ugolev is the first fundamental work in the area of space gastroenterology. It will be of great interest to both specialists in the field of space medicine and clinical gastroenterologists.

The book is well-illustrated (7 tables, 87 figures) and could serve as the foundation for future research and generalizations in the field of space gastroenterology.

ABSTRACTS OF ARTICLES FILED WITH THE ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF MEDICAL AND MEDICOTECHNICAL INFORMATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 16, No 4, Jul-Aug 82 pp 96-97

UDC: 629.78:616.12-003.7-02:[616.61-008.924.1+616.61-008.939.6]-092.9

PROTEIN AND CALCIUM CASTS IN WISTAR-SPF RAT KIDNEYS

[Abstract of article by A. S. Pankova]

[Text] The kidneys of 212 Wistar-SPF rats were examined morphologically: 72 animals flown aboard Cosmos-782, Cosmos-936 and Cosmos-1129 biosatellites, 72 kept in the vivarium (control animals) and 68 used in a ground-based model experiment. The animals were decapitated 5-13 h, 6 and 25 days after the flight and termination of model experiment. The kidneys were fixed in neutral formalin and imbedded in paraffin; sections were made of three different levels (15-20 sections on each level); they were stained with hematoxylin and eosin, according to Van Gieson, and calcium salts were demonstrated according to Koss.

Macroscopic examination of the kidneys of part of the rats decapitated after terminating the experiments revealed signs of hydronephrosis: the kidneys were flaccid, the cavity of the pelves was dilated and cortical substance thinned down. Macroscopically visible changes were encountered in 30-40% of the rats in the flight group, and only 8-12% of rats from the ground-based model experiment and vivarium control.

Microscopic examination revealed protein and calcium casts in a significantly higher percentage of cases (80-90%); they were demonstrable equally often in the kidneys of all three groups of rats examined. But the severity of involvement and extensiveness of the process were more marked in flight animals. While protein-calcium casts were found in a small number of tubules, situated mainly in the boundary zone, in the kidneys of rats in the control groups, we observed cystic dilatation of the lumen of the vast majority of tubules in the flight group of rats, and not only in the boundary zone, but other parts of the cortex and medulla. There were large (small in the control) layered or clumbed masses with admixture of calcium salts (stained according to Koss)

in the dilated lumen of the tubules. In some animals, we demonstrated changes in the glomerules of the internal hydronephrosis type--dilation of Bowman's capsule by filtrate.

We did not observe progression of changes in the kidneys 25 days after terminating the experiment; on the contrary, there was a tendency toward regression thereof; there was no proliferation of connective tissue around the tubules (Van Gieson stain). By this time, the differences between parameters of the groups studied disappeared.

In the available literature, we found an indication that Wistar-SPF rats sometimes develop hydronephrosis. In our case, it can also be assumed that we are dealing with a species-specific distinction of SPF rats, and spaceflight factors aggravated it. We cannot rule out the possibility that the pasty feed, which was specially developed to feed animals during spaceflights, played a provocative role in demonstrating the distinction of SPF rats. It is known that changes in proportion of trace elements (magnesium, phosphorus) in food are instrumental in development of nephrocalcinosis. Since all of the animals in our experiment received the same amount of feed identical in composition, the severity and extensiveness of the process of formation of protein-calcium casts in the flight group of rats could be indicative of impairment of calcium metabolism during the flight and in the readaptation period.

Bibliography lists 4 items.

UDC: 612.111.3.014.426

EFFECT OF STEADY MAGNETIC FIELD ON MORPHOLOGICAL COMPOSITION OF PERIPHERAL BLOOD

[Abstract of article by G. V. Cherkasov]

[Text] A study was made of the effect of a constant mangetic field (CMF) on morphological composition of peripheral blood. The studies were conducted on 200 male F_1 mice. Two series of experiments were conducted, with 3- and 24-h exposure to SMF with induction of 1.6 T. Blood samples were taken for analysis immediately after exposure to SMF , then 1 and 3 days after it. The following hematological parameters were studied: quantity of erythrocytes, reticulocytes, leukocytes, hemoglobin content of peripheral blood and spectrum of distribution of erythrocytes according to size. In the series with 3-h exposure to SMF, no changes were demonstrated in hemoglobin, erytrhocyte and reticulocyte content. Upon termination of 3-h exposure, there was a shift of the erythrocytometric curve. The specific share of macrocytes attained 25.45±0.74% in the experiment (versus 23.07±0.63% in the control; $P<0.02$). Leukocyte count of peripheral blood increased to 166% ($P = 0.002$) 1 day after exposure. The Price-Jones curve remained shifted to the right: the quantity of macrocytes constituted 26.75±0.72 and 24.78±0.53% in the experiment and control, respectively ($P<0.05$); microcytes constituted 6.81±0.6 and 9.33±0.83% ($P<0.02$). By the 3d day, leukocyte count dropped and constituted 127% of the corresponding control; however, the difference was not statistically reliable. By this time,

the size of erythrocytes of experimental animals did not differ from that of control mice. Immediately after 24-h exposure to SMF, the animals' peripheral blood showed an increase in reticulocyte and leukocyte count. Reticulocytosis attained 160% (P = 0.002) in relation to the corresponding control, and leukocytosis 159% (P<0.001). After 1 day, reticulocyte count dropped to 68% (P = 0.01), while leukocytosis remained at the former level. On the 3d day after exposure to SMF, the quantity of reticulocytes and leukocytes was somewhat greater than in control animals, constituting 111 and 120%, respectively. In this case, the differences between experimental and control figures were statistically unreliable. In the series with 24-h exposure, no changes were demonstrated in hemoglobin and erythrocyte content; there was an insignificant increase in erythrocytes only on the 3d day of the aftereffect period (107.4% in relation to the corresponding control; P<0.01). As with 3-h exposure, the erythrocytometric curves were shifted, without change in shape in the macrocyte region. This shift was statistically unreliable, and already on the 3d day the quantity of macrocytes was the same in the experiment and control, whereas microcytes constituted 13.01±0.78 in the experiment, versus 10.72±0.72% in the control (P<0.05).

The biphasic nature of the curve of change in reticulocyte content of peripheral blood after 24-h exposure, in the form of an initial increase and subsequent decrease, warrants the assumption that the increase in quantity of juvenile forms of erythrocytes is attributable to more than normal exit thereof from bone marrow without stimulation of erythropoiesis. The relatively rapid increase in diameter of erythrocytes of all sizes is apparently the result of change in either the physicochemical properties of blood plasma or permeability of erythrocyte membranes under the influence of SMF.

There are 2 illustrations; bibliography lists 5 items.

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CSO: 1849/6

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